Sustainable Development of Fishing Operations: A Case Study Focusing on Small Vessels in Palabuhanratu, Indonesia

By

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A Thesis

Submitted for the Degree of Doctor of Philosophy

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June 2019

Abstract

The key factor in promoting sustainable fisheries is implementing a sustainable fishing operation that is not only environmentally friendly but also economically viable and socially acceptable. To achieve this, fish resources, fishing technology, and the organisation of fisheries should be managed proportionally. Regarding fishing technology, most of the existing approaches discuss the development of ecologically safe fishing gear but disregard the fishing vessel itself, which inspire this thesis to develop a novel approach focusing on the fishing vessel. Therefore, the main goal is to develop and formulate best practices for sustainable fishing operations, concentrating on small-scale fishing vessels.

A case study was conducted in Palabuhanratu, a region with a significant number of small-scale fishing practices, which is typical of many fishing regions in Indonesia and other developing nations. This research investigates four principal types of vessels based in Palabuhanratu, specifically, pelagic Danish seiners, trammel netters, handliners, and lift netter. The selection represents the principal types of operations including active-passive fishing and demersal-pelagic fishing.

The research was carried out in four stages. Stage one sought to understand the existing fishing practices, which produced a fishing operation model. Stage two was a sustainability assessment, which elicited the environmental, economic and social impacts of the current operations. Stage three identified the possible measures to improve the existing performance. Stage four formulated best practices for implementing sustainable fishing vessel operations, which resulted in management measures derived from a trade-off between theoretical principles and potential implementation.

The results show that when considering the fishing vessel, passive operations are generally more sustainable than active operations. The research also reveals the importance of trade-off between environmental, economic and social performances when comparing overall sustainability, as no single operation performs well in all elements. In conclusion, this research demonstrates a comprehensive investigation on the performance of small-scale fishing vessel operations. In order to promote sustainable operations, best practice has been formulated by considering the contribution of all sustainability elements proportionally.

Acknowledgements

The completion of this Thesis could not have been possible without the assistances and supports of so many people whose names may not all be enumerated. Their assistances and supports are sincerely appreciated and gratefully acknowledge. However, I would like to express my deep appreciations particularly to the following:

1. My supervisors, Professor Richard W. Birmingham and Dr Alan J. Murphy for their countless support and constant expert guidance.
2. Directorate General of Higher Education (DIKTI), Ministry of Research, Technology and Higher Education – Republic of Indonesia for the scholarship and making my dream come true.
3. Indonesian Endowment Fund for Education (LPDP), Ministry of Finance – Republic of Indonesia for providing financial support for the fieldworks.
4. Palabuhanratu fishing port for providing data, information and professional assistance during the fieldworks.
5. Enumerators, informants, and respondents for the supportive cooperation during the fieldworks.
6. My examiners, Dr Oihane C. Basurko and Dr. Kayvan Pazouki, for their review, comments and suggestion on my PhD work.
7. Lynna, Serena, and Aisha, three indescribable friends which make my PhD life enjoyable.
8. My office mates, you come and go yet we shared ups and downs of PhD journey here, M1.11C.
9. Mbak Ira and the girl squads, my extended family who keep me mentally healthy along this journey.
10. My fellow PhD students at the Marine Technology, my fellow Indonesian PhD students, my house mates, and my colleagues at Bogor Agricultural University for the friendship and encouragement.
11. Finally, I would like to thank to my beloved family for their unconditional love and tireless support.

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Glossary of abbreviations, terms and symbols

A. Abbreviations

ALDFG	:	Abandoned, lost and discarded fishing gear
CAPEX	:	Capital expenditure
CDSI	:	Centre for Data Statistics and Information (Indonesia)
CPUE	:	Catch per unit effort
CSR	:	Corporate social responsibility
CUNO	:	Cubic number
DISPEX	:	Disposal expenditure
EEZ	:	Economic Exclusive Zone
ENVEX	:	Environmental expenditure
ep-EROI	:	Edible protein Energy Return on Investment; dimensionless ratio calculated by dividing the amount of edible protein yielded from the food to the energy required to produce the food
EPS	:	Expanded polystyrene
FAD	:	Fish aggregating device
FAO	:	Food and Agriculture Organisation
FGD	:	Focused group discussion
FU	:	Functional unit
FUI	:	Fuel use intensity; the amount of fuel required to produce a certain quantity of seafood product and it is represented per 1 kg catch and £1 revenue
FV	:	Future value
HDPE	:	High-density polyethylene
HL	:	Hand line
HNSI	:	Himpunan Nelayan Seluruh Indonesia (official name for Indonesian fishers association)
IHO	:	International Hydrographic Organisation
ILO	:	International Labour Organisation
IMO	:	International Maritime Organisation
IPCC	:	Intergovernmental Panel on Climate Change
IRR	:	Internal rate of return
ISO	:	International Organisation for Standardisation
ISSCFG	:	International Standard Statistical Classification of Fishing Gear
LCA	:	Life cycle assessment
LCC	:	Life cycle cost
LCI	:	Life cycle inventory
LF	:	Lift net
MAIB	:	Marine Accident Investigation Branch (UK)
MARPOL	:	International Convention for Prevention of Pollution from Ships
MMAF	:	Ministry of Marine Affairs and Fisheries (Indonesia)

MSC	:	Marine Stewardship Council
MSY	:	Maximum sustainable yield
NIOSH	:	National Institute for Occupational Safety and Health (USA)
NPV	:	Net present value
OECD	:	Organisation for Economic Co-operation and Development
OPEX	:	Operational expenditure
PD	:	Pelagic Danish seine
PLTU	:	Pembangkit listrik tenaga uap (Indonesian terms for steam-electric power station)
PP	:	Payback period
PPN Palabuhanratu	:	Pelabuhan Perikanan Nusantara Palabuhanratu (offical name of Palabuhanratu fishing port)
PV	:	Present value
RISKEX	:	Risk expenditure
SDG	:	Sustainable Development Programme
SEAFDEC	:	The Southeast Asian Fisheries Development Centre
SETAC	:	Society of Environmental Toxicology and Chemistry
SFC		Specific fuel consumption
SIA	:	Social impact assessment
S-LCA	:	Social life cycle assessment
SSFV	:	Small-scale fishing vessel operation
The Code	:	Code of conduct for responsible fisheries
TN	:	Trammel net
UN	:	United Nations
UNCLOS	:	United Nation Convention on the Law of the Sea
UNEP	:	United Nations Environmental Programme
WECD	:	World Commission on Environment and Development
DGOG	:	Directorate general of oil and gas, Ministry of Energy and Mineral Resources (Indonesia)
DGCF	:	Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries (Indonesia)

B. Terms

Active fishing	:	The vessel moves to operate the fishing gear
Demersal fishing	:	Fishing operation targeting the fish near the seabed
Ecoinvent	:	Database for inventory analysis in the LCA
Encircling	:	The fishing stage where the gear is encircled in the water to catch the fish
Fisher	:	A person who works on the vessel as the crew. The fishers is also used for referring the person who conducts the fishing operations in general.
Fishing attributes	:	Items attached to the fishing vessel operation
Fishing ground	:	The location where the fishing activity is conducted
Fishing input	:	Fishing attributes that are used for conducting the fishing operation

Fishing output	:	Fishing attributes that are produced from the fishing operation
Fish locating	:	The fishing stage where the vessel is looking for fish and deciding the spot to deploy the gear
Hauling	:	The fishing stage where the gear is pulled out from the water and the fish is collected from it
Impact2002+	:	Method to perform LCA
Input variables	:	Sets of values defined to calculate the profit of fishing vessel operation
Owner	:	A person who owns the vessel
Passive fishing	:	The vessel waits when the fishing gear is being operated
Pelagic fishing	:	Fishing operation targeting the fish near the surface
Port-based worker	:	The person who is responsible for handling the fishing vessel before and after the operation. This person does not involve in the fish catching process
Rumpon	:	A fish aggregating device which can be drifted, floated and anchored in the water to attract fish
Seller	:	The person who is responsible for selling the fish after the fish being landed at the port
Setting	:	The fishing stage where the gear is deployed in the water
SimaPro	:	A software used to run the LCA calculation
Skipper	:	The captain of the vessel
Soaking	:	The fishing stage where the gear is left in the water column to catch the targeted species
Steaming	:	Voyage between the port and the main fishing ground
Terms of trade	:	The ratio of the fisher's income to the fisher’s expenses.
Troll line	:	Fishing gear consists of lines with baited hooks and is pulled by a vessel
Vendor	:	The person who sells or produces items required to conduct the fishing operation

C. Symbols

Nm	:	Nautical miles
Rp	:	Indonesian rupiah
GT	:	Gross tonnage
r_i	:	CMA ratio
μ_i	:	Months
S_i	:	Seasonal index
v_s	:	Speed
t_s	:	Running time
Q_{fsum}	:	Total fuel consumption
Q_{fo}	:	Total fuel consumption at idle speed
ρ_f	:	Fuel density
Inf	:	Inflation rate
Dis	:	Discount factor

C_i	:	Net cash inflow in year – *i*
C_0	:	initial investment
$PV_{recurring}$	:	present value of all repeating expenses, including supplies, maintenance and personnel cost)
$PV_{residual}$	:	present value of residual value at the end of the lifetime
$C_{negative}$	:	cumulative cash flow until the last negative value appears
$C_{positive}$	:	net cash inflow, cumulative cash flow from when the first positive value appears
t	:	the number of years which $\Sigma C_{negative}$ appears

Chapter 1. Introduction

1.1 Background

Fish are believed to have been a food source for thousands of years. The simplicity of catching fish in shallow waters, which can even be performed by hand, allegedly made capture fisheries a part of the prehistoric culture (Gartside and Kirkegaard, 2009). A considerable amount of evidence is available in relation to prehistoric times, for example, the discovery of human fossils, fish bones, mollusc shells, and fishing tools surrounding shallow lakes, besides sculpted murals, which reveals that through fishing, humans fulfilled their daily needs. Over time, as populations have grown, demand for fish has increased, and technology has developed. Consequently, fishing has expanded from inland waters to open seas with million of tonnes of fish production from all around the world. Additionally, aquaculture has also evolved as a supplementary source of fish production.

In the modern world, the capture fisheries and aquaculture sectors continue to play a considerable role as a source of food. As reported by Food and Agriculture Organisation (FAO) the world's fish production significantly increased from just under 20 million tonnes in the 1950s to 169.2 million tonnes in 2015 (FAO, 2015b). More than a half of global fish production was obtained from developing countries, and their export value continued to grow from USD 18 billion in 1995 to USD 22 billion in 2005 and USD 35 billion in 2015. This value was considerably higher than land-based agricultural products such as rice, coffee and tea.

Regarding Figure 1.1, it can be seen that fish consumption increased from 6 kg/capita in the 1950s to 20 kg/capita in 2015, which confirms that the role of fish as a source of nutrients has become increasingly important. Examining its nutrition content, Sheeshka and Murkin (2002), claimed that fish are more nutritious than other sources of protein, such as chicken, beef and milk proteins, as fish contains higher amino acid which is good for growth. In addition, fish comprises Omega 3 which is beneficial for the human brain.

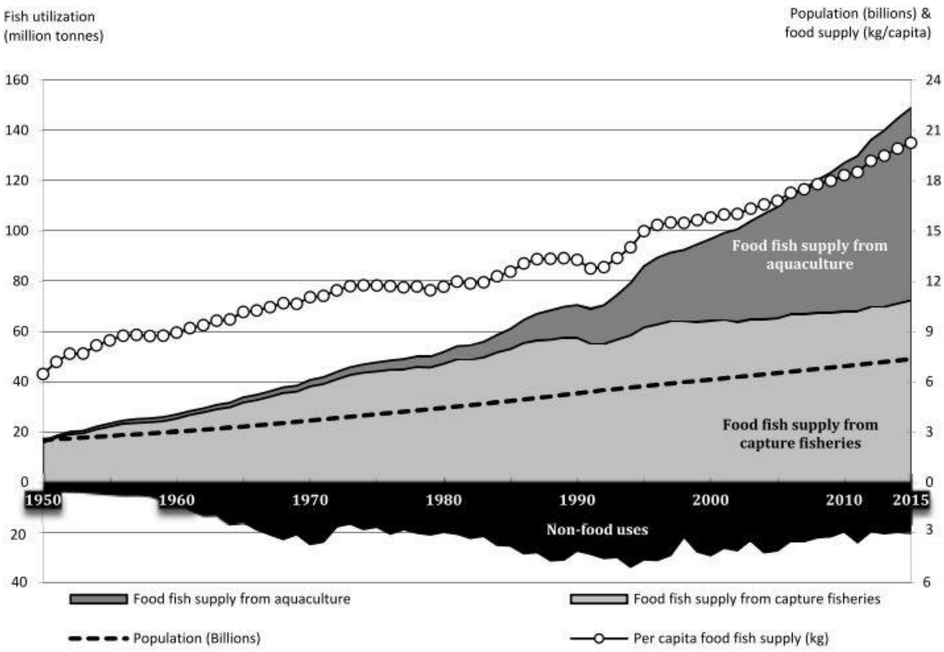


Figure 1.1 World fish production and utilisation from 1950 to 2015
(FAO, 2015b)

Fisheries also contribute to daily life by way of employment and economic activity. In the employment area, FAO reported that at least 37.8 million people work as fishers (FAO, 2015b). In terms of economic activity, the same report showed that about 35% of worldwide fish production is exported, and USD 133 million is produced via trade in this sector. In addition, the fisheries sector also has a multiplier effect in the development of support industries, such as fish processing, fish and fish product transportation, boat building and fishing gear production.

Figure 1.1 shows the world fish production incorporating aquaculture and capture fisheries sectors, and its utilisation as food and non-food uses. It can be seen that there has been considerable growth in aquaculture, which has increased by over 80% in the last two decades. However, it is predicted that aquaculture's future growth has limitations related to land use expansion (Chang *et al.*, 2016) and highly rely on the fishmeal which is produced from capture fisheries (Naylor *et al.*, 2009). Therefore, integration between aquaculture and capture fisheries in the future will be more visible. This means that the role of the capture fisheries sector as a source of food, employment and economic activities remains important and should be maintained for future generations.

However, capture fisheries are facing sustainability issues since the world's fish stock has been overexploited. The fish production peaked in the mid 1990's and has continued to decrease, as seen in Figure 1.1. It should be noted that the total production of capture fisheries presented in the figure includes the food and non-food supplies, which in total is decreasing since the mid 1990's.

According to Christensen and Tull (2014) and FAO (2016) the decrease in fish production is a result of excessive fishing practices. After the Second World War, when diesel engines and the price of fuel became cheaper, fishing vessels became larger with more powerful engines and substantially more capable fishing gear, additionally echo sounders were introduced for finding fish, which greatly enhance fishing efficiency (Gartside and Kirkegaard, 2009). In the short term, it is undeniable that intense fishing has increased fish supplies and economic livelihoods, however, in the long term, as explained by Garcia and Charles (2007), it has also led to fish stock depletion, marine ecosystem degradation, waste accumulation and increasing energy consumption. The fact that capture fisheries feed the world but require significant energy input and cause environmental damage has led some to believe that it should be sustained through large scale responsible fisheries management.

Prior to the 19th Century, when simple fishing was being practised using basic technologies, there was a common assumption that fish resources were unlimited. However, the development of people's understanding of ecology over the last two centuries has raised awareness that even though it is naturally renewable, fish resources should be maintained appropriately (Lackey, 2005). Concern related to the preservation of marine resources has been raised by the United Nations (UN) via the United Nations Convention on the Law of the Sea (UNCLOS) (UN, 1982). It is then followed by the report of World Commission on Environment and Development (WECD) also known as the Brundtland Report where the terms of sustainable development is introduced with the concept of three pillars of sustainability incorporating environmental, economic and social dimensions (WECD, 1987). With regard to sustainable development concept, Agenda 21 was held to encourage the local government to outline its own achievement programme, and the concern on sustainable development in marine resources is provided in Chapter 17 (UN, 1992). Subsequently, FAO developed the Code of Conduct for Responsible Fisheries (the Code), which specifically comprises guidelines to ensure sustainable development in fisheries (FAO, 1995). Besides, in 1991, the FAO Committee on Fisheries formulated a definition of sustainable development that can be applied to fisheries as the development of fish resource management in responsible manners incorporating environmentally friendly, technologically appropriate, economically viable and socially acceptable to ensure the satisfaction of human needs for present and future generations (Singh-Renton, 2001).

1.2 Research motivation

It should be mentioned that to comply with the development concept, fisheries management such as vessel licensing systems, fleet capacity control, vessel quotas, fishing gear regulations, controlled access to fishing grounds, and the development of marine protected areas has been extensively implemented to promote sustainable fisheries (Charles, 2001; Bjordal, 2002). Those measures refer to the central goal of management action which is restocking fish resources up to maximum sustainable yield (MSY) and controlling fishing pressure (Johnsen *et al.*, 2009). As a result, the assessment of fish stocks and dynamic populations considered in the context of wider economic forces, are the common basis for sustainable fisheries management measures.

However, according to the aforementioned fisheries impacts, promoting sustainable fisheries should not only be concerned with protecting fish stock but also about protecting the marine environment, as stated in Agenda 21, Chapter 17 and the Code (UN, 1992; FAO, 1995). Marine environmental protection requires fishing gear and fishing vessels which not only have a low impact on the environment, but that is also economically viable and socially acceptable for the users. The development of sustainable fishing gear has been manifested in various regulations and policies which aim to protect fish resources from irresponsible catching processes, and in addition research has been undertaken which focuses on selective and biodegradable fishing gear. With regard to the fishing vessels themselves, management measures have focused on controlling their fish capture capacity, but little attention has been given to developing vessels that are sustainable in terms of their manufacturing, operation and decommissioning. This research is endeavouring to respond in part to this challenge.

Sustainable fishing vessel design was studied by Wibawa (2016) who proposed a fishing vessel design for the Indonesian fisheries sector based on a sustainable development concept where the requirements of the pillars of sustainability were met. Different technologies including construction material, main engines, electricity power sources, fish preservation and fishing equipment were compared to propose the sustainable design which considers the environmental performance and socio-economics of fishers' communities. However, in order to maintain long-term fishing activities, fishing vessels should not only be designed responsibly but they should also operate in the same responsible way.

One of the major issues related to fishing vessel operations is energy consumption. According to Tyedmers *et al.* (2005), the energy used in these fishing activities constituted 1.2% of global fuel consumption and emitted 1.7 tons of CO_2 per-ton live-weight catch. In addition, when compared to other activities along the value chain of seafood products, the fishing process has resulted in the most significant impacts on the marine environment due to a significant amount of fuel consumption and emissions (Thrane, 2006). This is also confirmed by Kameyama *et al.* (2007), who concluded that throughout the service life of a ship, the most significant energy consumption and the environmental load was derived from the operation phase. Those studies justify that energy consumption and environmental loads pertaining to fishing operations, both in the fish production chain and with the perspective of a vessel's lifecycle, are important to address. Therefore, this research was designed to develop sustainable fishing vessel operations which consider the environmental, economic and social aspects.

Fishing vessels operated in marine waters are both powered to non-powered and range from vessels as little as 7 m in length to commercial vessels. A report published by FAO contained global fisheries data for 2014 and stated that powered marine fishing vessels accounted for 64% of the global fleet, of which 80% are based in Asia. Furthermore, approximately 85% of motorised vessels are small vessels, less than 12 metres in length (FAO, 2016). The domination of small vessels is not only found in Asia, the home of the vast majority of fishing fleets but also in other regions including Africa, Europe, Latin America and the Caribbean, North America, and the Pacific and Oceania.

For the management and statistics purposes, fishing vessels are classified into two groups, i.e. large-scale fishing vessel (LSFV) and small-scale fishing vessel (SSFV). Whilst the LSFVs typically are industrial vessels owned by companies, SSFVs belong to personal owners and are predominantly artisanal fishing. Further discussion about the classification of the fishing vessel is provided in Section 2.3.3. Artisanal fishing is fishing practices concentrated in coastal areas incorporating immense amounts of labour coupled with low investment, and being strongly linked to economy of the region (Borges *et al.*, 2006). However, due to limited fishing grounds and fish resources, artisanal fishing can be viewed as being unreliable, therefore, the livelihoods of the fishers are challenging and uncertain. In order to meet these challenges, this research is specifically aimed to develop sustainable operations of SSFV.

Indonesia is one of the fisheries nations which predominantly performs artisanal fishing. A statistical report from the Centre for Data and Statistics Information (CDSI, 2015) revealed that virtually 90% of vessels operating in Indonesian waters are less than 10 gross tonnage (GT) and fishing within 4 nautical miles (nm) from the coastline. Furthermore, at least 2 million people work as fishers. According to Kompas (2017), The Ministry of Fisheries and Marine Affairs (MMAF) claimed that fishers' prosperity had been improving, as indicated by the increase in the fishers' terms of trade from 104.63 in 2014 to 108.24 in 2016.

However, promoting sustainable SSFV operations, especially in Indonesia, is confronted by various challenges. Firstly, it should be mentioned that it is difficult to assess the current sustainability status, which is important in order to set milestones an improvement plan. Secondly, coastal communities have a strong patron-client relationship with conservative attitudes which typically resist change, therefore, management actions are frequently impeded by community reluctance. Furthermore, the conflict of interest between environmental, economic and social aspects requires the formulation of best practice which enable these to be integrated in order to have a positive influence. Lastly, data is not well recorded.

1.3 Research questions and objectives

Regarding the aforementioned challenges, two major questions arise in developing sustainable operations of SSFV in Indonesia.

1. What is the current status of the operations of Indonesian SSFV in terms of sustainability?

2. Considering the nature of fishing communities, what are achievable best practice for managing sustainable SSFV operations?

Accordingly, the main goal is to formulate best practice and implementation strategies in operating SSFV in a sustainable manner. The objectives of this research are:

1. To assess the sustainability of current small-scale fishing practices in Indonesia taking account of environmental, economic and social aspects.

2. To identify possible measures to improve current practices.

3. To formulate the best practice and implementation strategies.

The hypothesis in this research is sustainable development of SSFV operations, specifically in Indonesian coastal waters by a comprehensive assessment which incorporates environmental, economic and social aspect of fishing vessel operations.

1.4 General research methodology

1.4.1 Research site

A case study was conducted in Palabuhanratu West Java, Indonesia, located in the western part of Java Island directly facing the Indian Ocean (Figure 1.2). Palabuhanratu is the administrative capital of Sukabumi recency which is situated on the southwest coast of West Java, facing the Indian Ocean. The region has been bestowed with potential fisheries resources and evolved as one of the fishing business centres in West Java Province, even Indonesia. A national scale fishing port has been established since 1993 to serve fishing activities. Within a radius of 6 miles, there are several fishing villages which have smaller fishing ports, however, this research will only focus on the fishing operations and fishing communities which are based in Palabuhanratu fishing port, which officially is named as Pelabuhan Perikanan Nusantara Palabuhanratu (PPN Palabuhanratu).

This location was chosen as the research site for several reasons. Palabuhanratu fishing port is one of the business centres for the capture fisheries sector in Indonesia. It perfectly represents Indonesian fisheries as the port is the home for at least 600 vessels, ranging from 2 GT to 200 GT. About 80% of the fishing fleet is 5 GT or less and performs artisanal fishing. Those vessels operate eight types of fishing gears which are typically used by Indonesian fishers, specifically, longline, troll line, purse seine, lift net, trammel net, handline, pelagic Danish seine, and gillnet. Furthermore, the fishing port provides sufficient data to support the fisheries research.

Figure 1.2 Case study location, Palabuhanratu, Indonesia
(Google, 2018)

The research focused on the four vessels equipped with pelagic Danish seine, trammel net, handline, and lift net, which henceforth is referred to as pelagic Danish seiner (PD vessel), trammel netter (TN vessel), handliner (HL vessel), and lift netter (LF vessel). Those vessels are 5 GT or less and operate daily inside Palabuhanratu bay with a range from 5 to 40 nm from the fishing port. Vessels operating other gear are not included given that the vessels are larger than 5 GT, commonly conduct fishing outside the bay at a distance of at least 60 nm from the fishing port, and the minimum fishing trip is occurring once a week. Further details concerning the studied vessels are explained in Section 3.5.

1.4.2 Research framework

The development of sustainable SSFV operations was approached using system engineering, which was chosen due to its capability to deal with a complex system (Kossiakoff *et al.*, 2003) and its compatibility to support the development of a sustainable system (Utne, 2006; Day *et al.*, 2008). The implementation of system engineering was carried out in six steps incorporating need identification; requirement identification; performance specification; analysis and optimisation; conceptual design or solution; and verification and test the system, as adopted from Fet *et al.* (2010).

This research investigates the operations of PD, TN, HL, and LF vessels which incorporate activities from the preparation of fishing equipment until the fish is sold to the other parties. Furthermore, the vessels' characteristic such as the size, number of fishers, amount of supplies and length of the trips within the same fishing gear group is mostly similar (PPN Palabuhanratu, 2015). Regarding the investigation area and the homogeneity of the studied vessels, therefore the sustainability assessment was carried out on the single unit basis instead of fleet basis, which means that the assessment was carried out only in four vessels representing PD, TN, HL, and LF vessels.

The final result is expected to support the decision making process regarding the management of small-scale fisheries. Thus the targeted user is the decision makers at the government level and fishers as the main actor in marine resource utilisation. According to the research objectives, there will be three deliverables produced from this research, specifically, sustainability performance, possible measures and best practice. The next section elaborates the procedure to bring out each deliverable in accordance with six steps system engineering process.

1.4.3 Research procedure

Three deliverables were attained through four principal works, i.e. understanding the existing situation, sustainability assessment, possible measures identification, and best practice formulation. Furthermore, data collection was conducted in two fieldworks. The first fieldwork, conducted from September to November 2015, was aimed at understanding the current practices, which was done by observing the fishing operations and interviewing different groups of stakeholders. The second fieldwork, conducted from November to December 2016, mainly focused on the validating the assessment result and discussing the potential improvement measures with the stakeholders. Total respondents involved in this research is 231 people and its distribution is presented in Table 1.1. It can be seen that a wide range of stakeholders has been included in order to provide a comprehensive information about fishing vessel operations.

In the first visit, most of stakeholders were approached individually using one to one interview, whilst in the second visit, they were invited in the focus group discussion (FGD). Inputs from the FGD were then analysed to formulate the best practice and implementation strategies. The following paragraphs explain the procedure applied for this research which is in line with six steps system engineering process, as summarised in Figure 1.4.

Table 1.1 The distribution of respondents included in the research

Categories		1st Fieldwork	2nd Fieldwork
Age range	0 - 9	-	-
	10 - 19	10%	9%
	20 - 29	22%	11%
	30 - 39	20%	33%
	40 - 49	27%	30%
	50 - 59	16%	15%
	60 - 70	5%	1%
Occupation	Fisher	18%	22%
	Port-based worker	5%	-
	Skipper	7%	10%
	Owner	12%	24%
	Seller	3%	10%
	Vendor	4%	4%
	Boat builder	3%	3%
	Fish buyer	4%	3%
	Second hand good buyer	2%	-
	Government employee	3%	-
	Housewife	20%	10%
	Student	20%	9%
	Non-fishing related job	-	6%
Affiliation	No affiliation	20%	15%
	PD vessel	16%	18%
	TN vessel	14%	16%
	HL vessel	15%	18%
	LF vessel	18%	24%
	All vessel	16%	9%
Academic background	No formal education	3%	-
	Primary school	54%	63%
	Middle school	34%	25%
	High school	6%	10%
	Diploma/Bachelor	3%	1%
Working experience	Not working	20%	9%
	0 - 9	14%	20%
	10 - 19	19%	29%
	20 - 29	25%	30%
	30 - 39	16%	11%
	40 - 49	6%	-
Gender	Female	24%	14%
	Male	76%	86%
Total respondent		**152**	**79**

1. Understanding of existing situations.

    1. The research was started by studying global, national and local fishing practices from published works, news and reports, as well as exploring the supporting theories that is leading to a comprehensive research design as described in Figure 1.3.

    2. Subsequently, a case study was conducted by performing the first fieldwork. Data collection included statistic reports from 2009 to 2015, fishing operation profiles and the information from diverse stakeholders. This provided the main inputs for mapping the current situation, the modelling of fishing vessel operations and assessing the fishing impacts.

    3. The mapping identifies elements related to the operation of studied fishing vessels, which is elaborated in Chapter 3. It consists of the operational profile, the structure of the value chain, sharing system, and fishing attributes attached to the fishing operation. Fishing attributes refer to a collection of the fishing inputs and outputs of the fish catching process, such as the vessel, fishing gear, catch and revenue.

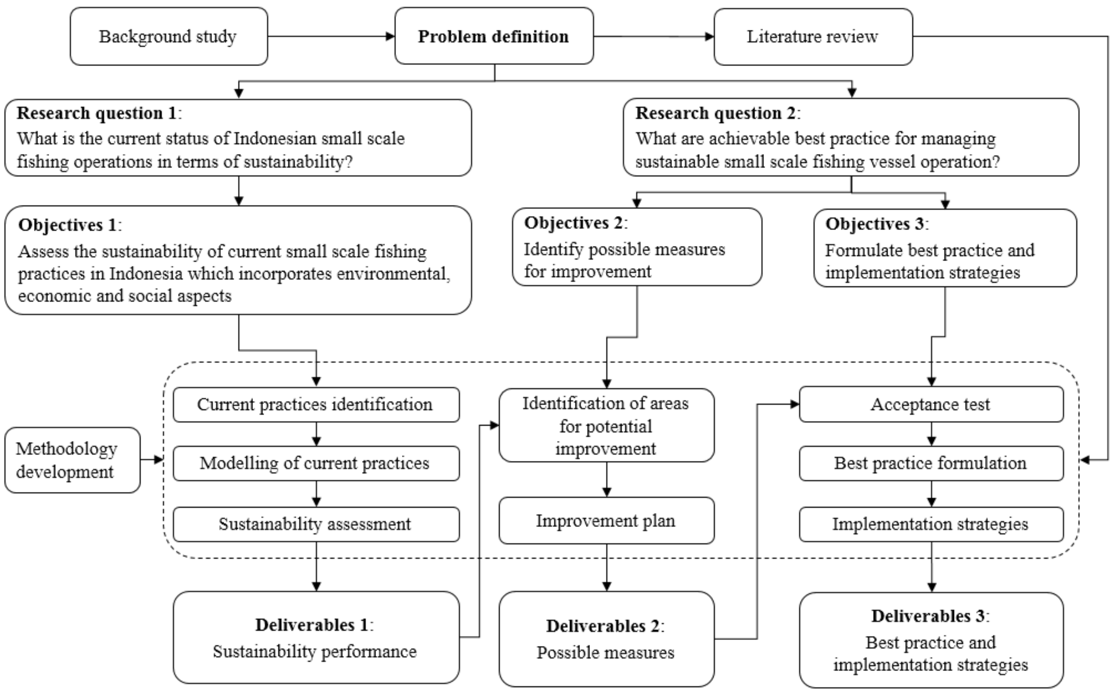


Figure 1.3 Research design

4. The fishing operation model which was based on the mapping results replicates the fishing activity and was eventually used to simulate different scenarios during the formulation of possible measures (see Point 3). Fishing vessel operation is a complex system, hence input variables used in the model were set out and the value for each variable was defined based on the survey results. The mapping, therefore, is also essential for this process.

5. The operation model depicts the existing fishing practices, which the further description is provided in Chapter 4. This completes the first stage of the research, which is aimed at understanding the current practice.

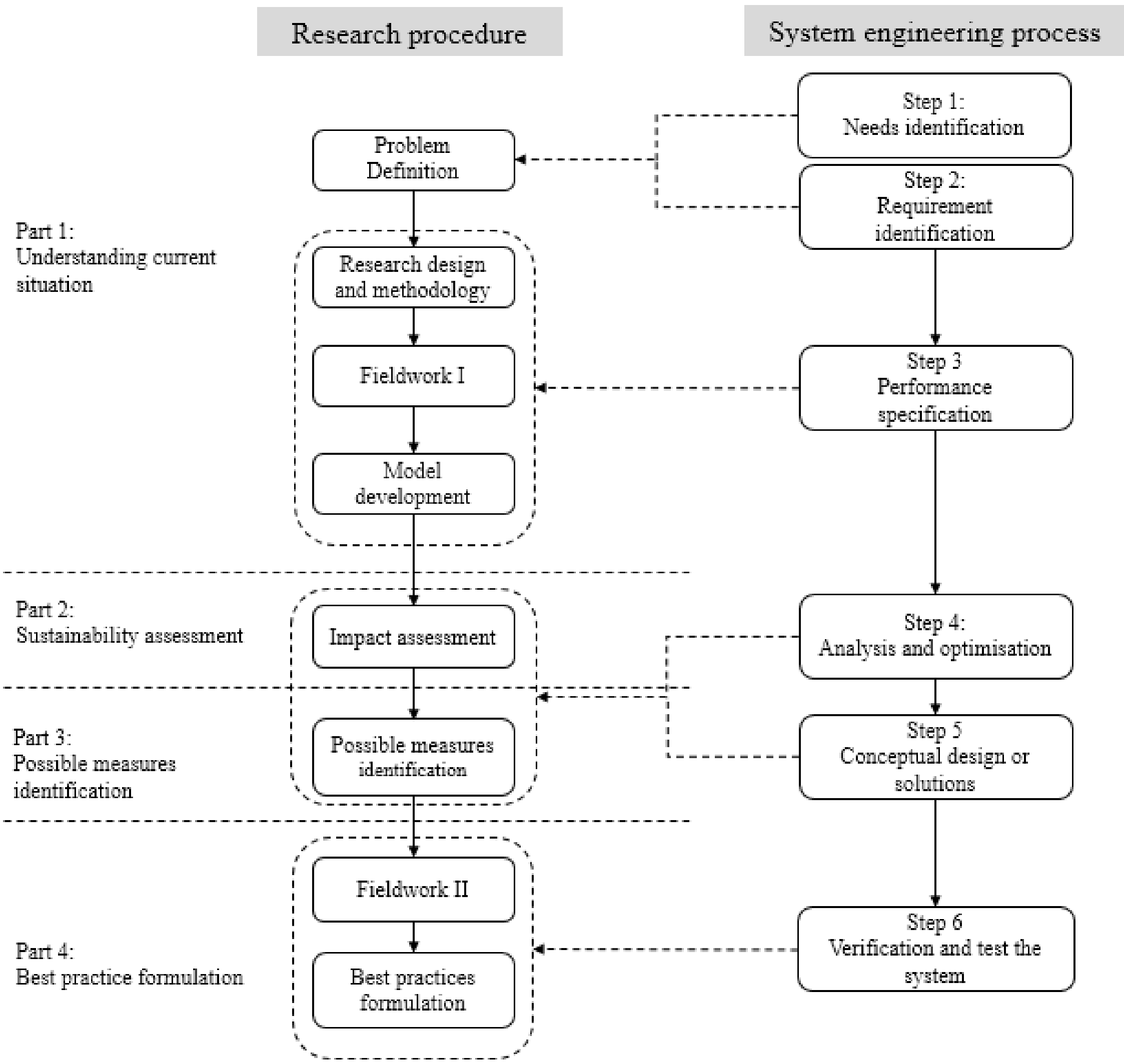


Figure 1.4 Research flowchart which is in line with the system engineering process

2. Sustainability assessment

   a. The second stage of the project started with the assessment of environmental impacts from the four studied fishing processes and was performed in three analyses namely energy consumption analysis, emissions analysis, and environmental life cycle assessment (LCA). Energy consumption analysis compares the fuel consumption against catch and its value represented in fuel use intensity (FUI). In addition, it also compares the energy yielded from landed fish to the energy inputs for a fishing process represented in edible protein energy return on investment (ep-EROI). Furthermore, the emissions analysis evaluates the CO_2 generated from the engine based on the emission factors.

      The LCA approach quantifies the environmental impacts throughout the vessels' operating lifetime using the IMPACT2000+ method with the calculation being run on SimaPro, a commonly used LCA software.

      The impacts were represented both in mid-point and end-point results. The mid-point reveals four environmental performance indicators, these being human health, ecosystem quality, damage assessment and climate change in different measurement units, whilst the end-point result aggregates these four categories into a single dimensionless number termed an eco-point. Later on, the result from each fishing practice was used as the baseline to formulate alternative strategies for environmental improvement.

   b. The next assessment is the economic impact, which was performed by means of three methods. Firstly, profit analysis was carried out to describe the profit distribution for different stakeholders. Secondly, a life-cycle cost (LCC) analysis is performed in order to calculate the total expenses over the operating lifetime of the vessel. Finally, a financial analysis was performed for each operation type in order to evaluate the feasibility of the fishing business and it was represented in net present value (NPV), payback period (PP), and internal rate of return (IRR).

   c. Subsequently, the social impact of fishing practices was also assessed using the life cycle perspective. Four groups of stakeholders involved both directly and indirectly in fishing operations were interviewed in order to gather information about social consequences of the SSFV operations. Furthermore, the social life cycle assessment (S-LCA) method was applied to analyse the information using a framework published by United Nation for Environmental Programme (UNEP) in collaboration with the Society of Environmental Toxicology and Chemistry (SETAC) (UNEP/SETAC Live cycle initiative, 2009; UNEP/SETAC Life Cycle Initiative, 2013). The result was described in six impact categories, specifically, human rights, working conditions, health and safety, cultural heritage, socio-economic repercussions and governance. It is quantified using performance analysis with an equal weighting system.

d. Assessment in point a, b and c were performed in four studied vessels representing PD, TN, HL and LF vessels. Afterward, the results from each vessel were compared to measure the sustainability performance. It was done by ranking the impact contribution from the least to the largest, and followed by scoring process to define the best fishing vessel operation.

e. Considerations underlying the selection of impact assessment methods are provided in Chapter 2, whilst the result of impact assessment is described in Chapter 5.

3. Identification of possible measures

   a. Following the assessment result, potential areas for improvement were identified using the information gathered in the first fieldwork and literature review.

   b. At this stage, possible measures were resulted from simulation at different scenarios using the fishing operation model and evaluation of its effects on environmental and economic performances. Regarding improvement in the social performance, possible measures were formulated based on the requirement to improve to the existing practice.

4. Formulation of the best practice

   a. Subsequently, the second fieldwork was conducted by inviting the stakeholders to evaluate the compatibility of the possible measures through an FGD. The FGD was classified based on stakeholder's role in fishing operations such as fisher, skipper and owner, with each group comprising 5-10 people. This process results in best practice, which refer to sort of achievable solutions based on the stakeholders' perspective.

   b. The formulation of implementation strategies is carried out afterwards. In order to provide a comprehensive improvement plan, the formulation of best practice and its implementation strategies were carried out in two levels, i.e. practical and policy levels. The practical measures recommend types of actions based on stakeholders' perspectives, whilst at the policy level, solutions are formulated based on the government's point of view.

c. Further detail about the formulation of best practice and implementation strategies is provided in Chapter 6.

1.5 Relevance to the United Nations Sustainable Development Goals

As part of the 2030 Agenda for sustainable development, the UN General Assembly has formulated Sustainable Development Goals (SDGs) consisting of 17 goals and 169 targets (UN, 2015). Figure 1.5 shows that it covers a broad range issues incorporating poverty, food security, health, education, climate change, water and sanitation, energy, industrialisation, human settlements, environmental protection and social justice. The sustainable development of SSFV operations strongly relates to Goal 14, which focuses on the conservation and sustainable utilisation of the oceans and marine resources. This goal has ten targets incorporating clean, healthy and productive oceans, as well as the sustainable use of marine resources, which should be ecologically friendly and profitable. Moreover, the protection of the small-scale fisheries is also emphasised.

Figure 1.5 United Nations Sustainable Development Goals
(UN, 2017)

In this thesis, the sustainability concerns are examined in relation to energy consumption, life cycle impact of the fishing vessels and the fishers' well-being. The energy consumption and life cycle of the fishing vessels are also related to climate change and sustainable production, whilst fishers' well-being is linked to poverty alleviation, food security and economic growth. Thus, it is argued that the sustainable development of SSFV operations relates not only to Goal 14, but also others such as Goals 1, 2, 8, 12 and 13.

1.6 Contribution to science and society

The sustainable fishing operation is not an instant and measurable result of this project. Therefore, the promotion and implementation of the result of this research will be in the form of publications such as journals and a book. This method is expected to influence and educate people who engage in the fishing industries such as fishers, students, researchers, academia, government and even entrepreneurs. For fishers, as the main actor, this project may connect their ideas to the other stakeholders and recommend eco-friendly fishing practices which are adaptable to their typical methods. For students, researchers and academia, the research outcomes provide information which may broaden their current knowledge and lead to a further sustainable fishing based project. Furthermore, this research may also encourage the government and entrepreneurs to take appropriate actions to promote sustainable fisheries through development of sustainable fishing vessel operations.

Chapter 2. Sustainable development of fishing vessel operations: a literature review

2.1 Introduction

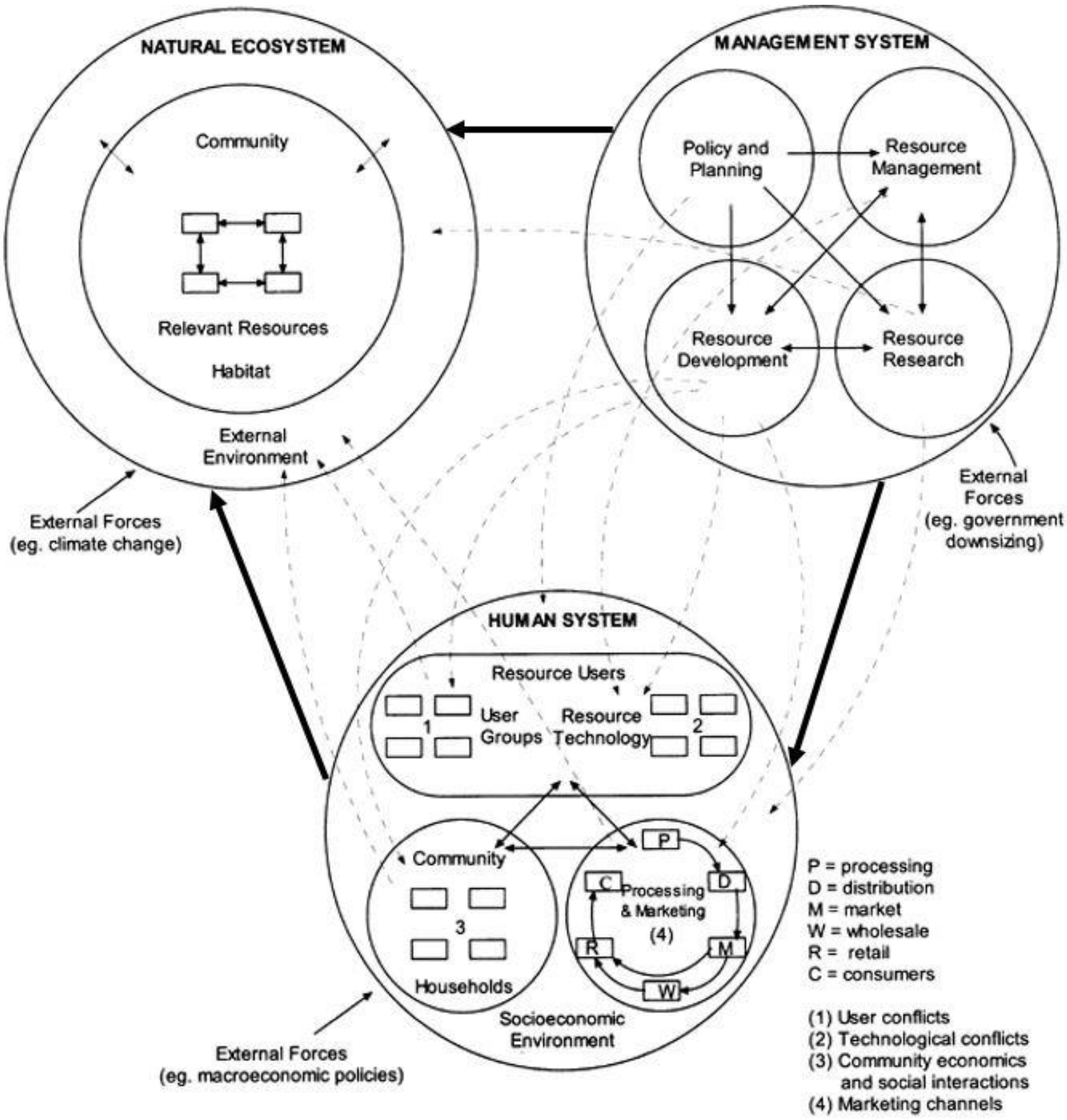
This chapter systematically describes the sustainable development of fishing vessel operations and comprises the definition of the capture fishery system, the management, challenges, and sustainable development concepts. A range of publications have been reviewed in order to provide background knowledge concerning the implementation of a sustainable development concept in the fishing vessel operation system.

2.2 Capture fisheries system

2.2.1 Defining the system for capture fisheries

Charles (2001), stated that a capture fishery is a complex system which consists of three principal subsystems, specifically, a natural ecosystem, a human system and a management system, which are linked together. The natural ecosystem, which relates to marine resources and the environment is resources that are exploited. On the other hand, the human system relates to exploitation activities which are carried out to fulfil the basic necessities of human life. In order to maintain productivity, or natural resources, and the fulfilment of human need, the exploitation of natural resources should be controlled via a management system which includes policies, management actions and research. Figure 2.1 from Charles (2001) is a diagrammatic representation of the complete interaction between the subsystems and their components and shows that humans are the subject of the system, natural resources the target, whilst management is the controller.

Fisheries management is a significant element in the capture fisheries system, which involves a number of approaches such as ecosystem, technical and human approaches. No comprehensive definition has been formulated, however, Cochrane (2002), concluded that the work attached to fisheries management is designed to maintain the optimal utilisation of marine resources. Although the ultimate goal is fish resources, Hilborn (2007), underlined that the core of fisheries management is actually managing people, which means that the human system is the centre of management action.



Note: The management subsystem controls the human subsystem, which targets the natural resources

Figure 2.1 Capture fisheries system
(Charles, 2001)

Regarding Figure 2.1, it can be seen that the human system incorporates fishing-related activities, processing and marketing activities, as well as people who are involved in the system including households and communities. The range of capture fishery activities is shown in the supply chain for seafood products (Figure 2.2a), which explains that prior to reaching the end customer, three production stages are carried out, specifically pre-harvest, harvest and post-harvest. Accordingly, Figure 2.2b shows the people who directly participate in those activities, in addition to households and communities indirectly associated with activities along the chain.

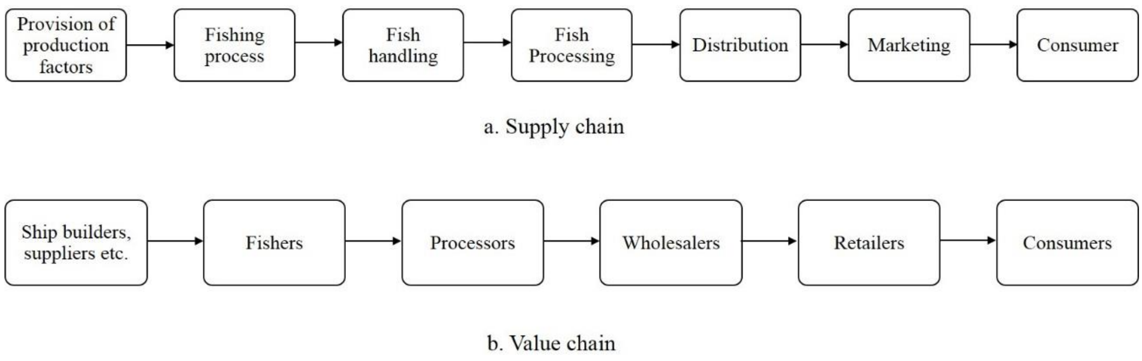


Figure 2.2 Supply chain and value chain for seafood products
(De Silva, 2011)

Regarding the number of actors involved along the value chain, fisheries clearly influence different groups of people by way of sale impacts, job opportunities and food supplies, as reported by FAO and other related organisations both at the international and national level. However, it is undeniable that the fisheries sector has caused environmental damage. The most remarkable impact is fish stock degradation, which is indicated by declining trends in world fish production since the mid-1990s (Watson and Pauly, 2001) and possibly caused by overfishing since the middle of the twentieth century (Pauly and Alder, 2005). It is also reported by the FAO (2014) that global overfishing trends tripled from 10% in 1974 to 30% in 2011. Furthermore, a study conducted by Thrane (2004b), concluded that along the supply chain for seafood products, the fishing process has resulted in the most significant environmental damage including fuel consumption, by-catch, ghost fishing (the wasteful capture of fish in lost and discarded nets) and damage to the seafloor. That fact emphasises that managing fishing operations is crucial in the development of sustainable fisheries.

2.2.2 Fishing operations and its environmental impacts

As an economic activity, a fishing operation generally refers to fish catching process and involves production factors including fishing vessels, fishing gear, fishers and consumables. Using all those inputs, the fishing process is undertaken and results in landed catch and profit as the output. The type of fishing gear and fishing vessels used during the catching process might vary depending on the fish target, habitat and the fishers' knowledge (Begossi, 2015; Jammu *et al.*, 2016), and the fishing method is adopted. Despite conventional fishing still being conducted without fishing vessels, most operations nowadays are performed using vessels that may operate in coastal and shallow waters as well as open and deep-sea waters. Furthermore, the scale of the operation also varies both in terms of the size of the individual vessels and the size of a specific fleet.

Fishing vessels will always be associated with the fishing gear that they employ and be named after it. According to the International Standard Statistical Classification of Fishing Gear (ISSCFG), there are 12 types of fishing gear incorporating different materials, design and operational methods and so the different types of fishing vessels can be classified based on the selected fishing gear (Nédélec and Prado, 1990). This classification is used globally and the details of both the fishing gear and the fishing vessel are shown in Appendix A. Furthermore, a broad distinction is made into two categories of whole equipment: passive and active gear (Bjordal, 2002). Passive gear waits for the fish to enter it, active gear is moved to capture the fish. From the fishing vessel perspective, Fyson (1985) has classified the operations into three main categories, i.e. towing or dragging, encircling and static vessels and it is used to design the fishing vessel. Further explanation about the classification of fishing vessel operations is provided in Section 2.3.1.

It is important to state that the environmental impacts of fishing operations can be due to both the gear and the vessel, and how the operation is carried out, as explained in the following paragraphs.

The most studied environmental impact in relation to fishing gear is the catch of unwanted species, referred to as by-catch, as a result of unselective fishing gear. By-catch is a major problem as it will affect the ecological niche and contribute to fish stock depletion. By using fishery-by-fishery approach, Kelleher (2005) estimated that the global discard from by-catch was 8% of the total catch, with an extremely low survival rate. Attempts to reduce by-catch numbers have been made through improvement of the fishing gear design, development of by-catch reduction devices, the landing and utilisation of by-catch which normally be discarded, and the implementation of spatio-temporal management (Matsuoka, 2008; Dunn *et al.*, 2011; Vazquez-Rowe *et al.*, 2011a).

Destructive fishing, which causes damage to the seafloor and coral reef, as well as killing more species than the targeted ones, is the next issue to address. Following the Code, the banning of dynamite, toxic substances and other harmful fishing practices have been extensively implemented, nevertheless, these illegal practices are still occurring (Bacalso and Wolff, 2014; Bailey and Sumaila, 2015). For example, coral reef study undertaken in one of small island in Indonesia reported that there an increasing dead corals and rubble within 44 years, which was primarily caused by fishing activities (Nurdin *et al.*, 2016).

When abandoned, lost and discarded fishing gear (ALDFG) continues to fish it is referred to as ghost fishing. This is also damaging as it can trap and kill many species, as well as disturb ecological communities by way of biotic invasion (Macfayden *et al.*, 2009). A study conducted on the northern coast of Australia estimated that the catch rate from ghost fishing could reach 4 turtles/100 metres of net. Since 2005, more than 13,000 nets have been removed from the seabed (Wilcox *et al.*, 2015). The importance of mitigating the ALDFG problem has been represented in the mandates of intergovernmental organisations and include a range of preventive methods such as gear marking, tracking technology and constant observation of passive gear (Gilman, 2015). Furthermore, the development of biodegradable fishing gear has been proposed to reduce the effect of ALDFG (Gilman, 2016; Kim *et al.*, 2016).

Regarding the vessel operations, a significant problem is derived from fuel consumption. In the context of sustainability, concern about fuel consumption has become increasingly important as all hydrocarbon fuels are derived from non-renewable fossil resources. Moreover, the situation is aggravated by pollution emitted from the vessels (Muir, 2015). The Code includes the requirement to optimise energy use during fishing operations, with the aim of protecting both the aquatic environment and atmosphere.

Furthermore, fishing vessels are also responsible for other types of pollutant such as dumping waste, oil spillage and leakages, along with ALDFG. The amount of waste per vessel is relatively small, however, in the highly concentrated fishing area, the accumulation of marine waste generated from fishing vessels might be considerable which require further action such as waste removal and incentive programme (Cho, 2009).

An additional problem attached to fishing vessel operations is safety issues, following the International Labour Organisation (ILO) report in 1999, it is still widely acknowledged that being a fisher is a high-risk occupation (ILO, 1999). The requirement to ensure the health and safety of the people working on-board has also been stated in the Code. Accordingly, the promotion of responsible fishing operation requires fishing vessels to be operated appropriately and safely.

Fishing gear has direct contact with fish, the seabed and the water column, therefore, their size, design, material, operating technique and deployment frequency affect the severity of environmental impacts. Furthermore, the wide variations in design have made possible to develop different types of eco-friendly fishing gear, such as trawl with a by-catch excluder device and gillnet with various mesh sizes. As a result, more studies related to managing responsible fishing operation have considered fishing gear. With the focus of this study on the fishing vessel, it is dedicated to enriching the existing knowledge on sustainable fisheries. Narrowing down the topic, the following discussion is in relation to fishing operations, followed by a further explanation of the impacts and the challenges in managing fishing vessel operations in Section 2.4.

2.3 The fishing vessel operation system

2.3.1 Defining the fishing vessel operation system

As a fishing unit, fishing gear, fishing vessel and fisher are inseparable within the context of fishing operations. As this study aims to address impacts from the perspective of fishing vessels, the term fishing vessel operation refers to all activities undertaken by the vessel to ensure that the fishing operation runs safely and smoothly. This encompasses all activities carried out from the moment a vessel leaves the port until it returns.

The function of most vessels is to transport people and freight, however, the fishing vessel is one of the few vessels which is constructed to work at sea. The state of fishing vessel's working pattern has been modelled comprehensively by Ervik *et al.* (1981), which is relevant to any existing fishing practice (Figure 2.3). The design, construction, capacity, and equipment of the fishing vessel should function optimally in order to locate the potential fishing ground accurately, operate the gear effectively, handle fish efficiently, as well as ensure that the crew is safe, and the fish landed is at the highest quality.

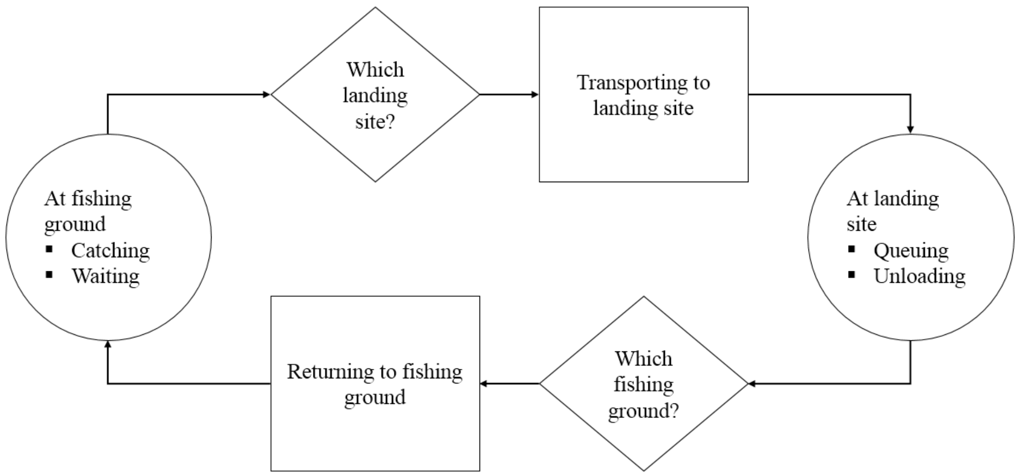


Figure 2.3 The state of fishing vessel's round-trip
(Ervik *et al.*, 1981)

According to Nédélec and Prado (1990) and Montgomerie (2015), the general technique pertaining to the operation of fishing gear incorporates setting and hauling the gear, while in between can be soaking, drifting or towing depending on the types of the gear. Setting is the process where the gear is submerged in the water. The process can be as simple as horizontally immersing the gear into the water, such as in hook and line fishing, or can be more complicated, such as when the gear needs to encircle the fish in order to fence in the school, as in purse seine fishing. Hauling refers to pulling the gear from the water, and can be performed shortly after setting, although it might also involve soaking, drifting or towing in between. Soaking is the process where the gear is left immersed in water after setting, drifting is when the gear is floated, whereas towing is when the gear is dragged through the water column. Whilst the first two aim to wait for fish to arrive, the latter practically chases the fish target.

The operational method of fishing gear will affect the operational profile of the vessel, including its design and specification. As previously mentioned in Section 2.2.2 that the fishing vessel operation is classified into three types, namely towing/dragging, encircling and static. Towing is when the vessel pulls the gear in order to catch the target species, for example when operating a trawl net, and so the main requirement of this vessel is a powerful engine. Encircling is when the vessel surrounds the fish target rapidly using the gear, therefore good manoeuvrability is an additional characteristic of the vessel which operates encircling gear, such as a purse seine. Static operation incorporates the soaking or drifting process and can take several hours, so vessels should be designed to ensure the seaworthy and sea-kindness.

Vessel performance and the fishers' skill play an important role in conducting a successful fishing operation. Furthermore, fishing productivity is not only influenced by the fish abundance, as a study conducted by Walden *et al.* (2014) showed that it was also affected by the capacity of production factors incorporating capital (fishing vessel and fishing gear), fishers, fuel, other supplies such as ice and bait, as well as port services.

2.3.2 Technical advancement of fishing vessel operations over time

In prehistoric times, people who lived near shallow lakes used their hands to catch fish, until the development of the spear approximately ninety thousand years ago. Roughly 50 thousand years later, archaeological evidence reveals that people started to use nets. This was followed by the development of the hook and line which is believed to have occurred about fifteen thousand years ago (Lackey, 2005). Meanwhile, coastal communities have been operating fishing boats for thousands of years, as revealed by Gartside and Kirkegaard (2009), who reported that reed boats equipped with cotton nets were used to fish for anchovies along the Pacific Coast (now Peru) between 2000 to 3000 years ago. Archaeological evidence also shows that vessels made of wood, skin, bone or a combination of materials were also used for fishing. Relying on human muscle and wind as a power source, operations were conducted using various types of fishing gear including spears, hooks and lines, and nets.

The invention of the steam engine led to the introduction of steam-powered fishing vessels in the 1860s which were capable of dragging nets and operating longlines. Since then, powered vessels have performed other activities which overcome the problems associated with sailing fishing vessels due to unfavourable winds (Sahrhage and Lundbeck, 1992). Another significant improvement in fishing vessels occurred via the introduction of the diesel engine. After the Second World War, mechanisation in fishing vessels became more intense because of the decreasing price of engines and fuel. Consequently, fishing capacity increased dramatically as larger vessels with more powerful engines and superior fishing gear became more popular (Gartside and Kirkegaard, 2009). After 1980, further innovation continued with the focus on increasing fishing efficiency through the development of fishing gear, fish finding equipment and fish aggregating devices (FAD) (Butcher and Boomgaard, 2004; Christensen and Tull, 2014).

2.3.3 Large-scale vs small-scale fishing vessel operations

Development in fishing operations has changed the nature of fishing from gathering to hunting and has increased peoples' dependency on seafood. Archaeological remains have demonstrated that humans who lived near Lake Mungo (Australia) around 30000 BP and Crete around 8000 BP were dependent on fishing (Lackey, 2005). Gradually, the role of fishing has evolved from providing food for family or clan to becoming a commercial activity. Furthermore, mechanisation on fishing vessels and improvements in fish preservation and transportation has encouraged the development of more commercial fishing, which has created two distinctive operations, namely commercial and artisanal. Commercial fishing refers to an operation run by companies which use large vessels and target national or global markets. Conversely, the latter is composed of personally-managed fishing operations which use smaller vessels and aims to supply local markets (De Young, 2006).

Furthermore, a study conducted by Therkildsen (2007), revealed that in terms of socio-economic parameters, small-scale fishing operations employ more fishers, use more vessels, and produce more money per ton of landed catch than the larger ones. In terms of environmental parameters, smaller vessels produce less by-catch but consume more fuel. Utne (2008), concurred with the finding, however, if the concept of sustainability prioritises safety indicators, larger vessels might perform much better than their counterparts.

Although both fishing practices literally exist, the differentiation between small-scale and large-scale fisheries remains unclear due to consideration of techno-socio-economic aspects (Ruttan, 2000). There is no universal definition, and the fisheries scale might be considered differently depending on the purpose, regions and criteria. Therefore, the FAO (2005), suggests customising the definition based on the nature of fisheries in specific regions. For example, the different criteria concerning small and large-scale fisheries from several countries in South East Asia have been summarised in Table 2.1.

In terms of fishing vessel dimensions, the FAO classifies vessels based on their length, thus: small is less than 12 m; the medium is between 12 and 24 m; and large is more than 24 metres (FAO, 2016). This length-based classification is for statistical purposes, hence, technology installed on board is not considered. It also means that "small vessels" are not necessarily traditional vessels conducting artisanal fishery. For example, numerous fishing vessels based in Europe and North America are less than 12 metres and equipped with advanced technology such as a fish finder, navigation system and mechanical fishing equipment, and in economic sense are operating commercially.

Similarly, statistics published by the MMAF Republic of Indonesia classifies fishing vessels as follows (CDSI, 2013):

1. Non-powered boats
2. Outboard-powered boats
3. Inboard-powered boats, which are further divided into different tonnage ranges including less than 5 GT, 5 – 10 GT, 10 – 20 GT, 20 – 30 GT, 30 – 50 GT, 30 – 50 GT, 50 – 100 GT, 100 – 200 GT, 200 – 300 GT, 300 – 500 GT, 500 – 1000 GT, and more than 1000 GT.

Due to ambiguity in definition of the SSFV, a clear definition should be given in order to provide a clear boundary for this study. Therefore, in this thesis, the SSFV is defined as a vessel which is 5 GT or less, traditionally operated along coastal areas and aims to supply the local market.

Table 2.1 Small and large-scale fishing operations

Countries	Small-Scale fishing operations	Large-Scale fishing operations
Cambodia	Using a vessel without an engine or with an engine ranging from 5 – 50 HP, conducting onshore operations up to a depth of 20 m.	Using a vessel which is powered by more than 50 HP engine, conducting offshore operations from a depth of 20 metres to the Economic Exclusive Zone (EEZ) limit.
Indonesia	• Using a vessel which is less than 5 gross tonnage (GT) or powered by a maximum 10 HP outboard engine, conducting onshore operations up to 3 nm. • Using a vessel which is less than 25 GT or powered by a maximum 50 HP inboard engine, operating between 3 and 7 nm from shore.	• Using a vessel which is less than 100 GT or powered by a maximum 200 HP inboard engine, conducting operations between 7 and 12 nm from shore. • Including all fishing vessels operated between 12 nm from shore to the EEZ limit.
Malaysia	Using a vessel which is less than 10 HP, operating from the shore to 5 nm	• Using a vessel which is less than 40 GT, conducting operations between 5 – 12 nm from shore. • Using a vessel ranging from 40 – 70 GT, conducting operations between 12 – 30 nm from shore. • Using a vessel which is larger than 70 GT, conducting operations from 30 nm up to the EEZ limit.
The Philippines	• Using vessels which are less than 3 GT, conducting operations from the shore to 15 km or the EEZ limit. • Using a vessel ranging from 3 – 20 GT, conducting operations within 15 km if the local government grant permission.	• Using a vessel ranging from 20 – 150 GT, conducting operations between 10 – 15 km if the local government grant permission • Using a vessel which is more than 150 GT and operating between 15 km and the EEZ limit.
Vietnam	Using a vessel which is less than 5 GT without an engine or powered by a maximum 40 HP engine, conducting operations onshore up to 30 or 50 nm, depending on the fishing area.	Using a minimum 5 GT vessel powered by at least a 40 HP engine, conducting operations between 30 or 50 nm and the EEZ limit.

Source: De Young (2006)

2.4 Challenges in managing fishing vessel operations

2.4.1 Energy consumption

In the fish supply chain system, shown in Figure 2.2, a certain amount of energy is used before the fish is served on the table. The energy consumed will depend on the type of processes involved in the chain (Thrane, 2004b). Even though in some cases fish processing can be more energy intensive than fishing, most researchers agree that the fishing stage itself consumes significant amounts of fuel (Eyjólfsdóttir *et al.*, 2003; Ziegler *et al.*, 2003; Thrane, 2004b; Hospido *et al.*, 2006; Muir, 2015); therefore, despite the fact that it will not provide a complete assessment, focusing this study on energy consumption during the fishing stage will give relevant calculations on particular fishery production chains.

Globally, fuel consumption on fishing activities, in terms of litres (l) of fuel per ton (t) of fish production, constituted 620 litres/ton in 2000 and accounted for 1.2% of global fuel consumption (Tyedmers, 2005). Based on the average calculation of fuel use since 1990, energy intensity displayed an increasing trend to 639 litres/ton (Parker and Tyedmers, 2015). Compared to other protein sources, the amount of energy spent on fishing is relatively high, however, the special characteristics of nutrition which is only found in fish, such as vitamin B12, balanced amino acid, low cholesterol, saturated fat and calories, and high polyunsaturated fat and fatty acid, has made fish an extremely important food source (Sheeshka and Murkin, 2002; Tilami and Sampels, 2017). Therefore, the fact that this exploitation of marine resources is exceedingly dependent on fossil fuel requires action to control the energy input as well as preserve the natural resources.

Historically, the concern related to energy in fishing started when it was observed that the increase in fishing effort was not proportional to increase fish production. Global fish production during the 1950s and 60s increased by 150%, identifying the sea as a promising food source for the future. Encouraged by low fuel prices, excessive fishing efforts continued into the 1970s. However, the increasing amount of fuel spent on fishing was not followed by comparable increase in fish production. The significant increase in the fuel price in the 1980s and signs of overfishing in some areas aggravated the situation and raised awareness with respect to energy efficient fishing.

To date, research related to energy use in fishing has typically focused on three topics: energy audits on individual vessels and fleets, fuel input assessment, and life cycle assessment (LCA) (Parker and Tyedmers, 2015). Energy audits aim to discover best energy saving practices by identifying the amount of energy supplied to the vessel and its application in the fishing process, including the components of the fishing vessels (Thomas *et al.*, 2010; Basurko *et al.*, 2012). An energy audit has different levels with each affecting the accuracy of the result and the recommendations. For example, According to the Australian Standard for Energy Audit, the audit is divided into 3 levels: 1, 2 and 3 (Australian/New Zealand Standard, 2000). Level 1 calculates the general energy consumption, Level 2 identifies the consumption and application pattern on the fishing vessels as well as hot spots for potential savings (Basurko *et al.*, 2013), whereas Level 3 focuses on the improvement of identified hotspots (Parente *et al.*, 2008). Collaboration with fishers plays a significant role in the energy audit, especially when conducting the audit level 2 and 3, as the fishers are involved in the data collection and analysis (Johnson, 2014).

Fuel input assessment, which is basically energy audit Level 1, associates calculating the energy use in particular fisheries with identifying potential saving practices in general. The study would investigate the level of energy use by comparing it with the available benchmark. Analysis on fuel input is commonly presented in FUI which refers to the amount of fuel required to produce a certain quantity of seafood product (Tyedmers, 2004). Additionally, as part of the food production system, ep-EROI is used when undertaking a comparison with other food products. This dimensionless ratio was calculated by dividing the amount of edible protein yielded from the food to the energy required to produce the food (Tyedmers, 2004). The scope of a study might vary at national (Thrane, 2004a; Schau *et al.*, 2009), regional and global levels (Tyedmers, 2005; Parker and Tyedmers, 2015). Geographically, very little research has been conducted in developing countries, with prolific research having been conducted in industrialised nations, such as Japan, Spain, America, Australia and the Scandinavian countries. However, data from the FAO (2007), shows that when compared to industrialised countries, developing countries consumed a significant amount of fuel.

Energy input on a fishing vessel can be divided into direct and indirect inputs (Tyedmers, 2004). Fuel input assessment is commonly related to direct inputs, i.e. fuel used during the fishing process. Indirect inputs are associated with the energy required to obtain the production factors, for instance, vessels, fuel, ice and fishing gear as well as for maintenance of capital goods. A study involving indirect inputs is typically found in the LCA research which has been receiving more attention since the early 2000s (Vázquez-Rowe *et al.*, 2012), and which is not only limited to the fishing stage (Hospido and

Tyedmers, 2005; Schau, 2012) but also considers the pre and post-harvest stages (Eyjólfsdóttir *et al.*, 2003; Thrane, 2004b). LCA research on fisheries is also centred on developed countries, nevertheless studies have evolved from only a few fisheries to diverse species, fishing vessels and fishing gear (Vázquez-Rowe *et al.*, 2012).

Studies related to energy use in fisheries are facing several common issues including data availability, methodology and implementation strategies. Whilst small-scale fisheries are mostly struggling with data gathering in general (Parker and Tyedmers, 2015), large-scale fisheries are hampered by data adequacy regarding longer time series analysis and detailed elements such as discard and bait (Vázquez-Rowe *et al.*, 2012). Furthermore, the complexity and diversity of fishing practices (Charles, 2001) in addition to the wide-ranging environmental impact indicators associated with energy use (International Organisation for Standardisation (ISO), 2006a) have resulted in variations in scopes, goals, system boundaries and methods. Therefore, energy use in fisheries is an extremely specific study whose implementation will only be suitable for the intended scope. In addition, researchers have been more encouraged recently to consider the socio-economic aspects when dealing with implementation proposals (Vázquez-Rowe *et al.*, 2012).

In this study, both direct and indirect energy inputs will be included in the impact assessment. Direct inputs are calculated from fuel consumption and presented in FUI per kg catch, FUI per £ revenue and ep-EROI. Meanwhile, indirect inputs are measured from resources used throughout the fishing vessel lifetime.

2.4.2 Pollution

As a result of fuel combustion, fishing vessels emit Carbon dioxide (CO_2), Sulphur oxides (SO_x), and Nitrogen oxides (NO_x) which make a significant contribution to global warming and acidification. The global fisheries report in 2000 confirmed that at least 1.7 tons of CO_2 was emitted to land 1 ton of fish (Tyedmers, 2005). Furthermore, considering its contribution to global CO_2 emissions from ships, fishing vessels were responsible for 4.5% of CO_2 emissions in 2015 (Olmer *et al.*, 2017). The number might also continue to increase following the increasing trend of fuel use in fisheries (Parker and Tyedmers, 2015). However, considering the amount of illegal, unreported and unregulated (IUU) fishing, with an estimated catch of between 11 and 26 million tons fish per year (Agnew *et al.*, 2009), the CO_2 emissions offered by the fishing sector is most probably underestimated. Therefore, even though it is reported as a small proportion, fishing operations might contribute significantly to global warming through greenhouse gas emissions.

Furthermore, through SO_x and NO_x emissions, fishing operations contribute to acidification which damages the human respiration system and marine ecosystem. The amount of SO_x and NO_x released from fuel combustion is highly dependent on the sulphur and nitrogen content in the fuel (Caslake and Garrett, 2009), and the engine load and combustion setting (Latorre, 2001; Lamas *et al.*, 2013). Unfortunately, global SO_x and NO_x emissions from fishing vessels remain unknown, however, some results from national scale studies have been published. A study conducted on the US fishing fleet revealed that at least 306 tons of NO_x were released per day (Latorre and Cardella, 2007), whilst in Taiwan, fishing vessels are responsible for 136 tons of NO_x/day and 54 tons of SO_x/day (Hua and Wu, 2011).

Apart from emissions, a study conducted by Richardson *et al.* (2017), revealed that approximately 71% of fishing vessel pollution is generated by dumping waste, followed by oil spillages and discarded fishing gear, which is responsible for 16% and 13% respectively. The type of waste discharged into the sea comprises plastic, batteries, metal and general waste. According to Chen and Liu (2013), many fishers tend to throw plastic food bags into the sea, however, in relation to other types of waste, such as plastic bottles, fishers prefer to take it back to port. Fishing vessels are also responsible for oil pollution through small spills. Indeed, in specific areas, fishing vessels and other small crafts can be a major sources of oil spillages, as reported by Washington Sea Grant (WSG) (2017), which suggested that fishing vessels and recreational boats are responsible for 75% of oil dumping in Washington State marinas over the last 10 years.

Numerous studies have been conducted to investigate the impact of marine pollution on marine living organisms, marine ecosystems and livelihood, especially fishing-dependent communities. As summarised by Richardson *et al.* (2017), the environmental drawbacks include ghost fishing, marine debris ingestion, the growth of harmful species, tourism and fishing business deficits, and the risks to navigation and safety at sea. Moreover, the detrimental impacts include marine ecosystem degradation, benthic zone disturbance and expensive marine pollution cleaning costs. Concerning the amount of pollution from fishing vessels and the impact on the environment, preventive measures are required to control pollution. The main regulation applied is the International Convention for Prevention of Pollution from Ships (MARPOL) 73/78, which established limits for pollutants discharged from ships. As the regulation is attached to large ocean-going ships, it is not applicable to most fishing vessels due to their low GT. The amount of pollutant generated from a fishing vessel is much smaller than that produced from a larger ship or land-based industry, however the fact that a substantial number of fishing vessels are operated worldwide suggests that significant amounts of pollutants accumulate, especially in areas with intense fishing activities.

In this study, air pollution generated from the fishing vessel will be focused on CO_2 emissions, due its contribution to global warming. Furthermore, the availability of comparable result and published emission factor enable to benchmark the level of emissions produced from the studied operations. Dumping waste, oil spillage and fishing gear discard are excluded from this study due to limited data source.

2.4.3 Safety issues

In 1999, ILO reported that fatalities in fisheries activities caused at least 24,000 deaths per annum, positioning fishing-related jobs as some of the most hazardous occupations (ILO, 1999). In the US, report from the National Institute for Occupational Safety and Health (NIOSH) (2015) shows that during 2000 – 2015, the fatality rate was 42 fishers/year, significantly higher than the US average (5 workers/year). Meanwhile, at least 10 fishers are killed each year in the UK (Marine Accident Investigation Branch (MAIB), 2014). Lumped with farming and forestry activities, fishing was also classified as one of the deadliest jobs in the UK (Seafish, 2016). Capsizing, fire, collision and man overboard are the most common fatal accidents (FAO, 2000; MAIB, 2014).

Despite the perilous working conditions, employment in this industry continues to increase, with significant growth occurring between 1970 and 1990, when the number of fishers, including fish farmers, roughly doubled from 13 million to 28.5 million (ILO, 1999). Furthermore, the FAO (2016) report which included more countries, also shows that employment solely from fishing increased from 34.2 million in 2000 to 37.9 million in 2014.

The fact that fish is an important food source but linked to a high-risk production system has led to efforts to improve the safety of fishing activities. In 1977, the first international convention on fishing vessel safety was conducted resulting in an agreement on minimum requirements for the construction of and equipment on fishing vessels. However, technical issues burdened the implementation until the Torremolinos Protocol, the revised version of the previous agreement, was published in April 1993. Subsequently, the International Maritime Organisation (IMO) reviewed the protocol in 2000 as a prerequisite of the enforcement and leading to a new agreement, which was adopted in 2012 (IMO, 2017). However, this international instrument is only applicable for fishing vessels larger than 24 metres in length (IMO, 1995). Therefore, considering the vast population of SSFVs, IMO has developed a code of practices for fishing vessels less than 15 metres in length (IMO, 2005). This was followed by recommendations that are specifically for decked vessels less than 12 metres in length and undecked vessels and was formulated in collaboration with the ILO and FAO (FAO et al.,2012).

The international instruments related to the safety of small fishing vessels are non-binding. However, law enforcement is important with respect to improvements in safety regardless of the size of the fishing vessel, therefore, the FAO encourages the formulation of national level regulations and technical standards that are more relevant to the nature of the fishing activities in each region (FAO, 2000).

Besides law enforcement, it is also generally agreed that safety in fishing vessels can be improved through comprehensive investigation of previous cases and the development of appropriate skills for the crew. Investigations aim to analyse the root cause of an accident and suggest preventive measures. To be successful, sufficient data is essential, however, a comprehensive analysis is typically burdened by limited accident records (FAO, 2000).

Human factors also make a substantial contribution toward occupational accidents, for example, lack of skill at navigation, training in handling the gear and most importantly survival at sea. Considering fishing skills, fishers employed in industrial fishing companies commonly develop their skills by means of formal education, whilst most of the small-scale fishers learn about fishing from personal experiences (McDonald and Kucera, 2007). Therefore, regardless of the various tasks undertaken during fishing operations, improvements in skills is essential to reduce potential risks (FAO, 2000), especially for those who have an informal educational background. Furthermore, because occupational risk tends to be underestimated by less educated fishers (Davis, 2012), education should not only focus on skills but also on awareness of safety issues (Benham, 2005).

2.5 Sustainable development of fishing vessel operations

2.5.1 The concept of sustainable fishing vessel operations

Considering the long-term fulfilment of the concept in sustainability, development of sustainable fisheries should not only concentrate on the protection of marine resources and their environment but also the socio-economic benefits for present and future generations (Singh-Renton, 2001). Furthermore, it involves multidisciplinary analysis, various activities such as observation, interview, and desk study, a wide variety of stakeholders, as well as adequate management systems (Charles, 2001). Providing comprehensive management measures which cover each fisheries element is almost impossible due to the complexity of fisheries, therefore, simplifying the concept into specific goals and opportunities allows for the successful development of sustainable fisheries (Utne, 2006).

As mentioned in Section 1.2, fishing operations are essential role throughout the fisheries supply chain, hence the sustainable development in fishing vessel operations will greatly support the achievement of sustainable fisheries. Furthermore, according to the Code (Article 8), the term “responsible fishing operation” is used to address fishing practices which consider safety, environmentally friendly fishing methods, a balanced ecosystem, environmental protection, energy optimisation, and good administration (Appendix B). Sustainability is principally a multi-interpretation concept which can be modified depending on the area of interest (Elliott, 2006). Considering the focus on the fishing vessel and the aforementioned terms, sustainable fishing vessel operations in this study, therefore, refer to fishing vessels which implement responsible fishing practices as suggested by the Code, which consider the economic and social benefits shared amongst the stakeholders.

2.5.2 System engineering approach

Sustainability is a multidimensional analysis which cannot be approached by using a single scientific discipline. According to the concept, it is clearly seen that the main challenge in developing a sustainable fishing vessel operation is bridging the interdependencies between environmental, economic and social aspects. Those three aspects should be considered proportionally, hence, it requires an understanding of the complete system and its future continuation (White, 2013). In correlation with need satisfaction, conflicts of interest between different stakeholders (Figure 2.2b) is also a further issue to address. Conflict is not only limited to different types of stakeholders but also to a wider range of potentially conflicting interests including those of present and future generations, of humans and nature, of poor and rich, and of the global and local communities (Elliott, 2006).

Furthermore, developing sustainable solutions is about the implementation of management actions which are formulated through the decision-making process. As a consequence, the use of decision-making tools such as Analytical Hierarchy Process, Cost-Benefit Analysis and Quality Function Deployment is essential in fisheries management. However, the use of assumption and expert judgment, as well as the specific scope of analyses, has limited the applicability of existing tools for sustainable development purposes. Therefore, Utne (2007), introduced the system engineering approach to develop the sustainability of fishing fleets. This tool is capable of accommodating multidisciplinary analysis and reducing the bias in recommendations resulting from assumption and judgment. In the context of sustainable development, system engineering has also contributed to the amalgamation of the environmental, economic and social aspects of the studied system (Pearce *et al.*, 2012).

Essentially, system engineering refers to breaking down the system into smaller tasks. However, theoretically, according to Kossiakoff *et al.* (2003) system engineering is a tool to "*guide the engineering of a complex system*" which focuses on the entire system, customer needs and the operational environment. Furthermore, it provides a conceptual design that connects different specialities. The types of complex system, which system engineering is commonly applied to are weather satellites, traffic control and power plants.

In fisheries, only a few studies have applied system engineering. The use of system engineering was essentially introduced by Hamlin (1986), who developed a specific fisheries model to obtain the best fishing vessel for particular fisheries in the USA. This study claimed that system engineering is efficient and consistent in modelling and the continuous evaluation of the fishery system. Additional applications of system engineering in fisheries were conducted by Fet *et al.* (2010), who developed a framework for the environmental assessment of seafood production systems, and by McGuinness and Utne (2014), who applied the tool for safety management of the Norwegian fishing fleet. Recently, Wibawa (2016) applied system engineering to propose a sustainable design for fishing vessels in Indonesia.

Considering its applicability, the system engineering approach will be used to guide the decision-making process in this research. It consists of several steps and as an iterative process, continuous evaluation is required throughout the study. One analysis has defined four main steps related to implementing system engineering, which are requirement definition, functional definition, physical definition and design validation (Kossiakoff *et al.*, 2003). However, in order to provide detail assessment, this research applied six steps adopted from Fet *et al.* (2010) as follows.

1. Needs identification: the need is identified based on the stakeholders. As there are various stakeholders in fishing activities, clear identification of who will be included in the assessment is essential. The concept of "need" can be interpreted in numerous ways, therefore, here, need is limited to the stakeholders' expectations towards the system.

2. Requirement identification: whilst need is related to stakeholders, the requirement is associated with the system. It identifies the requirement of the system to work appropriately in order to fulfil the needs. In terms of sustainable development, which comprises the three pillars, the requirement to meet the stakeholders' needs should include environmental, economic and social aspects.

3. Performance specification: this step aims to convert the requirement into a quantifiable specification using where possible numerical indicators and parameters. Subsequently, the performance of each indicator is assessed as the starting point for the improvement plan.

4. Analysis and optimisation: at this stage different system alternatives are evaluated to improve the existing performance.

5. Conceptual design or solution: a new design or solution is proposed based on the result obtained from the previous stage.

6. Verification and test: the proposed solution is then tested against the requirement formulated at an earlier stage.

2.6 Life cycle assessment

2.6.1 Life cycle concept

The application of system engineering is associated with the life cycle concept as the development of a complex system requires inputs from the entire life cycle (Kossiakoff *et al.*, 2003). Furthermore, regarding sustainable development, assessment is required to assist the decision-makers to determine the most appropriate management actions (Kates *et al.*, 2001). Given that sustainable development is concerned with responsibility for future generations, the life cycle concept is essential in relation to delivering appropriate assessment, which includes environmental, economic and social impacts (Kloepffer, 2008). Accordingly, it can be seen that the system engineering and life cycle approaches are compatible with sustainable development studies, hence, these approaches will be applied to this study.

The role of the life cycle assessment in sustainable development was acknowledged by the introduction of Life Cycle Thinking in 1992 by the UN and refers to the identification of the cycle of products or services along with their potential impacts (Azapagic, 2005; Kloepffer, 2008). This approach allows the decision-makers to choose long-term actions by considering the impacts throughout the lifetime of the system.

There are three life cycle methods which can be employed in the sustainability assessment: environmental life cycle assessment (LCA), life cycle cost (LCC) and social life cycle assessment (S-LCA) (Kloepffer, 2008). Whilst LCA is associated with the investigation of the potential environmental impacts of the product or service throughout its life cycle, LCC calculates the entire cost component, whereas S-LCA examines social performance.

2.6.2 Environmental life cycle assessment

Research conducted by Vázquez-Rowe *et al.* (2012), revealed that LCA has been applied in fisheries-related studies since 2005, and furthermore, that at least 33 research studies have been published by 2012. Most of the research investigated global warming and ozone depletion, as indicators of the environmental impact, however, a few expanded the discussion to comprise environmental hotspots and suggest improvement plans (Thrane, 2004b; Hospido and Tyedmers, 2005; Winther *et al.*, 2009; Vázquez-Rowe *et al.*, 2010; Svanes *et al.*, 2011; Vazquez-Rowe *et al.*, 2011b; Ziegler *et al.*, 2011; Vazquez-Rowe *et al.*, 2012). Recent research conducted by Wibawa (2016), provides a clear example regarding developing a sustainable fishing vessel by considering the environmental impacts throughout its lifetime and combine with stakeholders' preferences. This study concludes that existing fishing vessels are the most acceptable sustainable fishing vessel in terms of material, engine, electricity resources and fish preservation.

LCA is an internationally standardised tool to assess the environmental impact (Kloepffer, 2008). According to ISO 14040:2006, the general framework to conduct life cycle assessment consists of four steps, as described in Figure 2.4 (ISO, 2006b; ISO, 2006a). Generally, it refers to LCA with the possibility of applying it to both LCC and S-LCA. The first stage clearly provides basic information pertaining to the study, such as purpose and motivation, the boundary of the assessment, functional unit, data requirement, impact assessment method and assumptions. In the inventory stage, the categories of data required to quantify input and output of the studied system throughout its lifetime are listed.

Subsequently, in the third stage, impact assessment is conducted incorporating six steps, specifically 1) the selection of impact categories, indicators and characterisation models; 2) classification; 3) characterisation; 4) normalisation; 5) grouping; and 6) weighting. The first three steps are compulsory, whilst the remaining are optional. Finally, the interpretation stage evaluates the correlation between the assessment result and the defined goal and scope to support the decision-making process.

The result of the impact assessment can be presented either in endpoint or midpoint (Bare *et al.*, 2000). Whilst endpoint focuses on a higher level of aggregated environmental problems, for instance human health and ecosystem quality, midpoint focuses on a single environmental problem which contributes to the endpoint result, for example acidification and global warming. Despite the fact that endpoint is easier to understand and interpret, both levels provide valuable information with respect to the decision making process (Goedkoop *et al.*, 2016). The use of midpoint and endpoint is highly dependent on the purpose of the study.

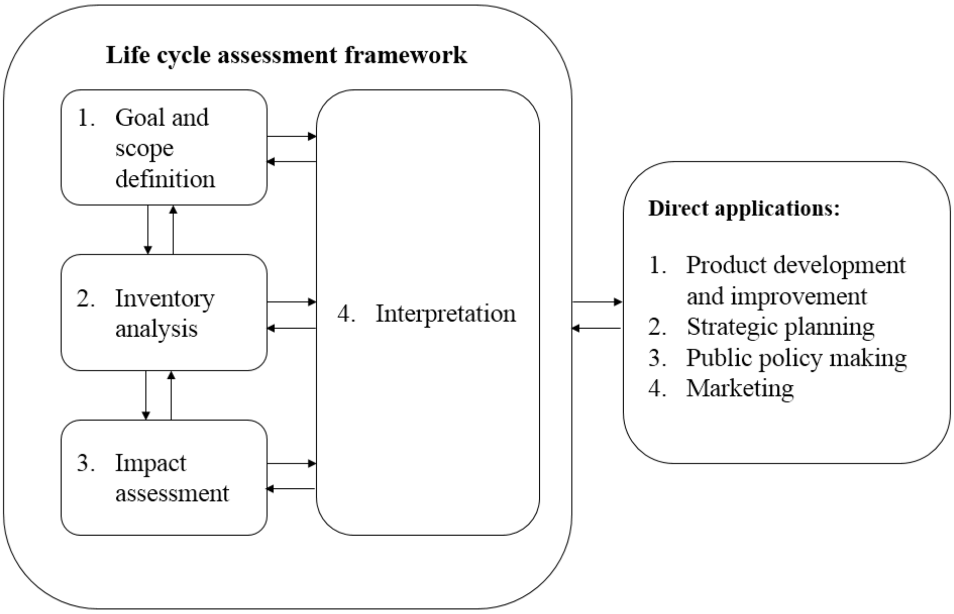


Figure 2.4 Life cycle assessment stages
(ISO, 2006a)

The result of the impact assessment can be presented either in endpoint or midpoint (Bare *et al.*, 2000). Whilst endpoint focuses on a higher level of aggregated environmental problems, for instance human health and ecosystem quality, midpoint focuses on a single environmental problem which contributes to the endpoint result, for example acidification and global warming. Despite the fact that endpoint is easier to understand and interpret, both levels provide valuable information with respect to the decision making process (Goedkoop *et al.*, 2016). The use of midpoint and endpoint is highly dependent on the purpose of the study.

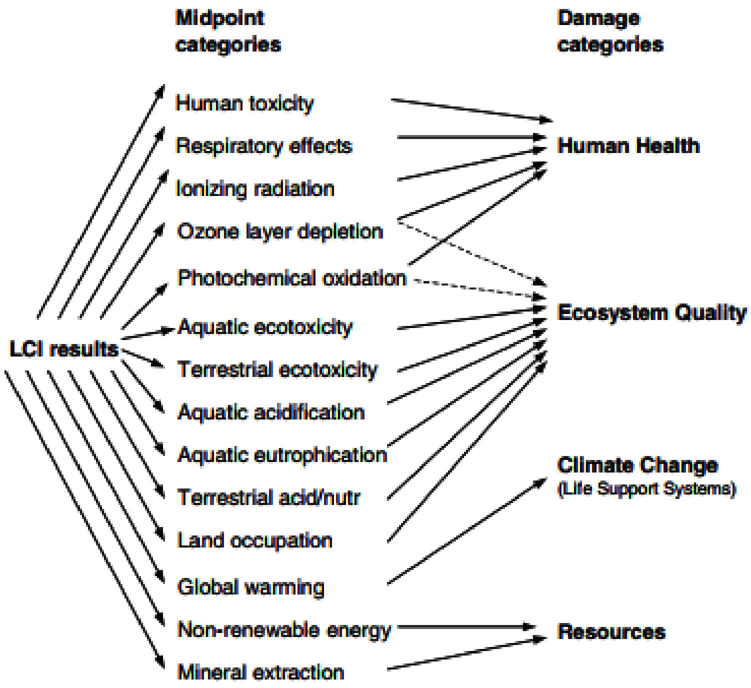
Conducting LCA is a complex task due to the requirement to consider a long list of inventories and multiple impact categories. Therefore, a number of analysis tools, such as GaBi, OpenLCA, Qantis suite 2.0, REGIS 2.3 and SimaPro have been developed to support different assessment purposes (Lehtinen *et al.*, 2011). In this study, SimaPro v8.5.2.0 multi user was used to perform the LCA because according to PRé Sustainability (2018) as a widely used software, it is user friendly and has a wide range of databases including Ecoinvent 3, European Life Cycle Database (ELCD), agri-footprint and industry data 2.0.

Database is the collection of data for general material production, transportation and waste treatment, which are required to support the inventory analysis (Goedkoop *et al.*, 2016). It is an essential aspect in the LCA process because not every single data can be obtained directly by the researcher due to time and resource limitations. This study primarily used Ecoinvent 3, while some processes were calculated using Industry data 2.0 and ELCD. Those three databases were selected because of the availability of information.

Furthermore, SimaPro provides various assessment methods, such as ILCD, CML, Ecological scarcity, EDIP 2003, EPS 2000, Impact 2002+ and ReCiPe. For the purpose of this study, IMPACT 2002+ was applied due to several reasons as summarised from Jolliet *et al.* (2003), Menoufi (2011) and PRé Sustainability (2016). Firstly, it is a new methodology which is capable of combining midpoint and endpoint by linking all types of inventory results. Additionally, the method is the combination of four methods including Impact 2002, Eco-indicator 99, CML and IPCC. In fact, this method is primarily based on Eco Indicator 99, one of the most widely applied LCA methods, which only applies the endpoint approach.

In SimaPro, other methods which also provide both midpoint and endpoint approaches are EPS and ReCiPe. However, EPS 2000 excludes the global warming impacts, whilst ReCiPe is unable to show the climate change impacts in the endpoint result, which is highly considered in this research. Furthermore, in the ReCiPe, both midpoint and endpoint calculations are performed using different procedure, however, in this research, the IMPACT 2002+ is preferred since both calculations are carried out in the same algorithm.

The IMPACT 2002+ method was firstly established at the Federal Institute of Technology Lausanne (EPFL), Switzerland, and it is now under further development by the IMPACT modelling team. According to Jolliet *et al.* (2003), this method performs the assessment in 5 steps i.e. classification, characterisation, damage assessment, normalisation and weighting. The method is also formatted for other software including Quantis SUITE 2.0 and GaBi. The version available in SimaPro is v2.12. This version characterises the inventory result into 14 midpoints indicators, which are subsequently grouped into four damage categories and normalised to produce endpoints. Using a default weighting factor, which assumes that all impact categories are equally important, aggregation into a single score is possible. Figure 2.5 illustrates the assessment framework applied in IMPACT 2002+, whilst Table 2.2 describes the main sources for the characterisation factor, reference substances and damage unit. Further details concerning this method can be found in Jolliet *et al.* (2003), (Humbert *et al.*, 2012) and PRé Sustainability (2016).



Note: LCI (life cycle inventory) is the process of creating inventory flows for a studied product/system

Figure 2.5 IMPACT 2002+ assessment scheme
(Jolliet *et al.*, 2003)

2.6.3 Life cycle cost

The most common accounting analysis in fisheries research remains limited in relation to evaluating fisheries investment by means of financial analysis, for example deciding the best fishing vessel to invest in (Tietze *et al.*, 2005), cost-benefit analysis (Sims-Castley and Hosking, 2003; Macher *et al.*, 2008) and viability study (Adeogun *et al.*, 2009; Schuhbauer and Sumaila, 2016). Due to the requirement to perform life cycle based analysis, LCC is applied to assess the economic impact of fishing vessel operations. The study conducted by Utne (2009), one of a few studies implementing the LCC approach in the fisheries sector, shows that this method can be applied to improve the sustainability of the Norwegian fishing fleet, despite various challenges, for instance data availability and monetary unit.

Table 2.2 Main sources for characterisation factor, reference substances and damage unit applied in IMPACT 2002+ (version Q2.12)

Midpoint category	Midpoint reference substance	Damage category	Damage unit	Normalised damage unit
Human toxicity (carcinogens + non-carcinogens)	kg chloroethylene equivalents into air (kg C_2H_3Cl eq)	Human health	DALY	Eco-point
Respiratory (inorganics)	kg $PM_{2.5}$ equivalents into air (kg $PM_{2.5}$ eq)			
Ionizing radiations	Bq Carbon-14 equivalents into air (Bq C-14 eq)			
Ozone layer depletion	kg CFC-11 equivalents into air (kg CFC-11 eq)			
Respiratory organics	kg Ethylene equivalents into air (kg C_2H_4 eq)			
Aquatic ecotoxicity	kg Triethylene glycol equivalents into water (kg TEG water)	Ecosystem quality	PDF·m^2·y	Eco-point
Terrestrial ecotoxicity	kg Triethylene glycol equivalents into soil (kg TEG soil)			
Terrestrial acidification/nutrification	kg SO_2 equivalents into air (kg SO_2 eq)			
Land occupation	m^2 Organic arable land (m^2org.arable)			
Aquatic acidification	kg SO_2 equivalents into air			
Aquatic eutrophication	kg PO_4 equivalents into P-limited water			
Global warming	kg CO_2 equivalents into air (kg CO_2 eq)	Climate change (life support system)	kg CO_2 eq	Eco-point
Non-renewable energy	MJ primary	Resources	MJ primary	Eco-point
Mineral extraction	MJ surplus			

Source: PRé Sustainability (2016). DALY = Disability-Adjusted Life Years; PDF = Potentially Disappeared Fraction of species; -eq = equivalents; y = year

By definition, LCC is a tool of analysis which incorporates all costs associated with the product life cycle. Factually, the development of LCC was started in the 1960s, when the US Department of Defence used this method to improve cost effectiveness (Sherif and Kolarik, 1981). Since then, the application has been adopted for industrial and consumer areas, followed by some technical evolvement.

A study conducted by Gluch and Baumann (2004), listed ten LCC-orientated environmental accounting tools, such as LCC, total cost assessment, full cost accounting and life cycle accounting, from a number of studies, which can be used to perform accounting analysis for sustainable decision-making. Presented in various names, those tools are basically similar in both method and structure.

In this study, LCC is conducted by accumulating the total expenses throughout the life time of the product/process, as adopted from Utne (2009). Generally, the cost components considered in LCC include capital expenditure (CAPEX), operation and maintenance costs (OPEX), disposal expenditure (DISPEX) and externalities which consists of risk expenditure (RISKEX) and environmental expenditure (ENVEX). It should be noted that not every component will be relevant to the studied system.

ENVEX is all expenses associated with environmental impact generated from the product or process, whilst RISKEX refers to all costs spent to cover the risk. Regarding the application in this study, these data are unavailable. For ENVEX, it is because no financial consequence is regulated in relation to the environmental impact of fishing operations. Furthermore, for RISKEX, the insurance and accident costs are not well recorded. Therefore, in this study, only CAPEX, OPEX and DISPEX are considered in the assessment. DISPEX consists of waste treatment cost and residual value. Since no data is available for waste treatment, this study only considers the residual value.

LCC deal with the future cost. Hence, the assessment should incorporate time value of money due to the difference between the present value and the future value (Davis *et al.*, 2005). Accordingly, inflation and discount rate should be considered in the calculation.

2.6.4 Social life cycle assessment

According to Lehmann *et al.* (2011) the assessment of social sustainability can be performed by several approaches including the integration of social issues with environmental impact assessment, social impact assessment (SIA) and S-LCA. The first two approaches are more common in practice and furthermore, S-LCA is recently gaining more attention. Both SIA and S-LCA have been developed as complementary tools for environmental assessment**.** Guidelines in relation to SIA were produced by the USA government as the initiator, whilst S-LCA guidelines were produced by UNEP.

SIA and S-LCA have different objectives, scope analysis and assessment procedures. The SIA focuses on specific actions, impacts are investigated based on a single process, and the assessment is conducted using different impact categories depending on the project type and stage of development. Conversely, S-LCA focuses along the product's lifetime, which means that impacts occurring throughout the studied period are investigated. Furthermore, the assessment is performed using a set of indicators classified based on the stakeholder types or different impacts categories, which can be selected based on the characteristics of the studied project. Despite the major difference, both methods agree that stakeholders play an important role. It is plausible, as quantification of social indicators is a burden in measuring the social impacts, hence, it is approached by collecting stakeholders' opinions and applying a scoring system to produce reference points (Benoit *et al.*, 2010).

Regarding implementation in the fishing industry, the most common impact assessment in fisheries is approached by SIA. The method examines the costs benefits of management actions and policies in relation to history, culture, demography, economic and ecology, thus, the assessment can be performed either qualitatively or quantitatively (Bradshaw *et al.*, 2001).

The vast majority of social impact studies in fisheries are focused on poverty alleviation on a large scope. It ranges from simulating the public transfer of income (Daniels, 2002), analysing existing household income (Borges *et al.*, 2006), proposing management actions for poverty reduction (Njifonjou *et al.*, 2006; Cochrane *et al.*, 2011) and evaluating the impact of the existing fisheries management and policies in relation to sustainable livelihood (Isaacs *et al.*, 2007; Briones and Garcia, 2008; Tewfik *et al.*, 2008; Sowman *et al.*, 2014). Narrowing down the scope, selected studies investigated the impact of a quota management system on different fishing communities and suggested action plans which suit the character of each community (Wingard, 2000; Bradshaw *et al.*, 2001). It can be seen that SIA generally measures change in well-being caused by a specific project or programme and it focuses on a single phase of a project or product's life cycle.

S-LCA, in contrast, calculates the impact derived from the entire life cycle, and as lifecycle perspective is the back bone of this research, S-LCA is implemented to assess the social sustainability of fishing vessel operations. Recognising that the SIA approach is more popular, there is limited application of S-LCA in fisheries research. Applying the new approach is expected to provide a different insight for social sustainability.

Summarised from Fan et al. (2015), the development of the S-LCA method is explained as follows. The method was first developed from SIA in 2006, initiated by the thought that LCA should not exclude the social aspects. Consequently, this led to the introduction of the extended LCA scope, which includes human well-being and was followed by the development of S-LCA framework. Since the concept of human well-being is imperceptible, defining the representative data is the major challenge. Therefore, the improvement continued with the focus on developing socio-economic indicators and the method to quantify and aggregate the impact throughout the life cycle. This has resulted in various S-LCA methods, with the main distinction lying in the impact indicators and quantification methods. The most extensively used methods are developed by Norris (2006), Dreyer *et al.* (2006), Dreyer *et al.* (2010), Hunkeler (2006), Weidema (2006b) and Weidema (2006a).

Despite these diverse methods, no agreed rule exists with regard to conducting S-LCA. However, there is a guidelines developed by UNEP *et al.* (2009), which provides the contextual concept, framework, and consideration points in the S-LCA process. The basis of S-LCA is subcategories that represent social attributes attached to five groups of stakeholders. The subcategories are subsequently classified into six impact categories in which the S-LCA results are presented. This means one impact category can be correlated with several stakeholders, likewise one stakeholder can be influenced by some impact categories. Subcategories are gauged by inventory indicators which are characterised by a set of measurable inventory data. Indicators used in the assessment process can be diverse depending on the characteristics of the studied project or product and the community associated with it. Table 2.3 describes the assessment system suggested by the guidelines, whilst Table 2.4 details the subcategories identified under the stakeholder groups, which will be grouped into impact categories. It is important to note that the classification can be customised, as no standard is applied.

Table 2.3 Assessment system applied in S-LCA

Stakeholder categories	Impact categories	Subcategories	Inv. indicators	Inventory data
Workers	Human rights			
Local community	Working conditions			
Society	Health and safety			
Consumers	Cultural heritage			
Value chain actors	Governance			
	Socio-economic repercussions			

Source: (UNEP et al.,2009)

Table 2.4 Stakeholder group and subcategories

Stakeholder categories	Subcategories
Stakeholder "worker"	Freedom of Association and Collective Bargaining Child Labour Fair Salary Working Hours Forced Labour Equal opportunities/Discrimination Health and Safety Social Benefits/Social Security
Stakeholder "consumer"	Health & Safety Feedback Mechanism Consumer Privacy Transparency End of life responsibility
Stakeholder "local community"	Access to material resources Access to immaterial resources Delocalization and Migration Cultural Heritage Safe & healthy living conditions Respect of indigenous rights Community engagement Local employment Secure living conditions
Stakeholder "society"	Public commitments to sustainability issues Contribution to economic development Prevention & mitigation of armed conflicts Technology development Corruption
Value chain actors* not including consumers	Fair competition Promoting social responsibility Supplier relationships Respect of intellectual property rights

Source: (UNEP et al., 2009)

Unfortunately, no S-LCA application is found in the assessment of social impacts in fisheries-related studies. In this study, the S-LCA method is calculated by adopting S-LCA practice performed by Manik *et al.* (2013), who investigated the production of palm oil biodiesel in Indonesia. The study was chosen due to several reasons. Firstly, it is one of very few S-LCA studies conducted in Indonesia, related to natural resource use activities, dealing with similar stakeholders' composition, applying a site specific study, and using impact categories rooting in the UNEP/SETAC Life Cycle Initiative framework. Manik *et al.* (2013), developed the assessment by weighing and appraising the social impact indicators, as illustrated in Figure 2.6. Weighing was defined using the importance ranking suggested by expert opinions, whilst the appraising was calculated from the gap between the stakeholders' perspective and expectations. The impact score was obtained from the multiplication of the gap and the weight.

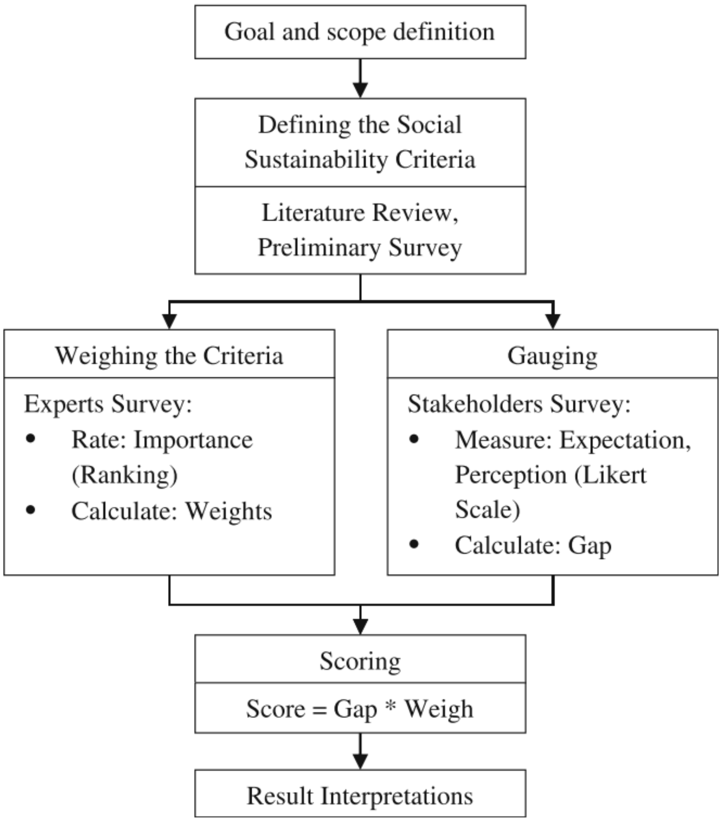


Figure 2.6 Assessment framework used in Manik *et al.* (2013)

2.7 Modelling the fishing vessel operations

A model is an essential tool used to perform the study, which deals with system and cost investigation, such as a fishing vessel operations. In relation to the financial aspect, modelling a fishing vessel operation is basically projecting the profit by calculating the gross income and operational costs. This paragraph summarises the concept of modelling the fishing vessel operations introduced by Dahle (1981). There are three aspects that should be considered during the modelling of the fish catching process including fish biology, fishing gear and its efficiency and the vessel. Fish biology is related to the prediction of potential catch, fishing grounds and fishing time, which can be completed based on information relating to fish stock size, fish distribution and fish behaviour.

Fishing gear and its efficiency are associated with the gear construction, resistance and operational method, which affect the catch volume. The vessel is linked to fishing time allocation, fuel and the requirement of other supplies, as well as crew size. Furthermore, prices, which are highly dependent on the market situation, are used to value the fishing process. The model can be very complex. For estimating a one trip operation, numerous variables should be considered such as fish abundance, gear size, total projected area, gear resistance, vessel speed, effective fishing time and distance from the fishing base. Subsequently, the monthly or annually productivity can be projected by multiplying by the number of fishing trips. However, it can be simplified by directly estimating catch/trip, fuel and other supplies/trip, the number of fishers, the number of fishing trips and prices. Considering data and time limitations, this study uses the simplified version.

In relation to LCA, the modelling is applied to describe the boundary of the assessment and the flows of the studied system from cradle to grave (Stavropoulos *et al.*, 2016). The flow of the system is modelled using LCA software, such as SimaPro, which is applied in this study. As the simplification of a complex system, distortions are unavoidable, therefore, Goedkoop *et al.* (2016) suggest defining the goal and scope of the assessment cautiously, as it affect the modelling process.

2.8 Summary

When described as a complex system, fisheries connect three sub-systems incorporating the natural ecosystem, the human system and a management system. Accordingly, managing fisheries involves various work which requires multidisciplinary approaches. Nevertheless, the core of management action is basically managing people in the utilisation of fisheries resources.

Fishing plays a vital role in human life due to its significant contribution to economic development and animal protein resources. However, exploitation of fish resources is also responsible for the degradation of the marine environment and the reduction of fish abundance. Consequently, fishing operations should be managed responsibly in order to minimise the environmental impacts while fostering the socio-economic benefits.

The environmental impacts of fishing operations are primarily derived from the gear and the vessel. Many studies have focused on the impacts caused by fishing gear, however, this research focuses on impacts produced by the fishing vessel. The operation of the fishing vessel is associated with all activities from the moment the vessel leaves the port until its return. Using all the production factors including the fishing vessel, the fishing gear, labour and consumables as inputs, the fishing operation is carried out and produces a landed catch as the outcome. According to fish target species and fishing gear, the vessel can be operated in three different ways: towing/dragging, encircling and static, with each having a different impact.

Significant technical development that occurred after Second World War is responsible for the increase in fish exploitation globally. Unfortunately, it is not aligned with fishing efficiency. As although more fuel is consumed in the fisheries sector, there is a decrease in the fish production. As a result, concern has increased significantly with respect to energy efficiency.

Furthermore, technical advancement in the fishing industry has also encouraged the development of larger commercial fishing which has resulted in two distinctive types of operation, namely large-scale and small-scale. However, the differentiation between those two remains fuzzy due to consideration of the techno-socio-economic aspects. A clear definition is typically provided for both statistical or study purposes. In this study, the SSFV is defined as a vessel which is 5 GT or less, traditionally operated along coastal areas and aims to supply local markets.

Managing fishing vessel operations generates several challenges. Firstly, fishing activities consume a considerable amount of non-renewable energy and produce air pollutants which harm human health and contribute to global warming. Secondly, apart from emissions, which are directly associated with fuel consumption, the fishing vessel also contributes to additional marine environmental degradation in the form of waste dumping, oil spillages and leakages, and the ALDFG, which harms marine organisms. Lastly, due to dangerous working conditions, fishing has become one of the riskiest jobs, as various statistical reports show a high fatality rate. These issue have been the motivation for this study to develop sustainable fishing vessel operations.

In this study, sustainable fishing vessel operation is defined as a fishing vessel which is operated in a responsible manner as suggested by the Code, including the consideration of socio-economic aspects. Given its multidimensional nature, the main challenge in developing sustainable fishing vessel operation is bridging the interdependencies between the three pillars of sustainability. Therefore, the system engineering approach which is capable of accommodating multidisciplinary analysis is applied in this study. Briefly, the sustainability of existing fishing practices will be assessed using the life cycle approach, which is subsequently used to formulate improvement strategies.

Chapter 3. Understanding existing small-scale fishing vessel operations

3.1 Introduction

This chapter consists of two key parts: 1) the current state of fishing vessel operations globally, in Indonesia and in Palabuhanratu; and 2) the existing practices of SSFV in Palabuhanratu. The description of the current state, including fishing vessels, fishers, fish resources, and fishing productivity, is aimed at providing background knowledge of the significance of SSFVs. Furthermore, the existing practices in Palabuhanratu, which are described based on a survey, depict the operational profile of SSFVs. These provide the basic information for the development of the fishing vessel operation model, which is discussed in Chapter 4.

3.2 State of global fishing vessel operations

Table 3.1 summarises data relating to fishing vessel operations including regional percentage of fishing vessels, fishers, fish production, and catch productivity, published in Fisheries and Aquaculture Statistics 2015 (FAO, 2015b). It should be noted that the data is derived from capture fisheries, specifically, marine and inland waters.

Table 3.1 Summary of global fisheries statistics 2015

Regions	Population		Fishers/ vessel (person)	Fish production	Productivity (ton)	
	Fishing vessels	Fishers			Fishing vessel	Fisher
Asia	75%	78%	9	55%	15	2
Africa	15%	14%	8	9%	13	2
Latin America and the Caribbean	6%	5%	8	12%	40	5
Europe	2%	1%	4	15%	144	40
North America	1%	1%	4	6%	67	18
Oceania	0.2%	0.1%	5	1%	154	33

Source: FAO (2015b)

3.2.1 Fishing vessels

In 2014, the number of fishing vessels operating globally was roughly 4.6 million. From the table, it can be seen that the vast majority, 75%, is based in Asia. Furthermore, regarding the powering systems, 64% of the global fishing fleet consists of engine-powered vessels. Figure 3.1 illustrates that the percentage of motorised fishing vessels in Asia is 68%, slightly higher than the global average. The percentage of motorised vessels in Europe and North America is virtually 100%. In contrast, the majority of the fishing fleet in Africa operated without an engine, roughly constituted 65%. Considering the recent technical development in fisheries, the number of vessels without engines is significantly high. At least 1.6 million vessels still rely on wind or human strength. These vessels generally operate in inland or shallow waters, and deploy small passive gear which does not require high power. From an environmental perspective, it is a friendly operation due to low or even no fuel consumption, however, from the socio-economic perspective, it is less positive due to lower productivity, low catch capacity and limited markets.

Categorising vessels by size and using length over all (LOA) as the metric demonstrates the preponderance of small vessels, which make up 85% of the total and the small proportion in the largest vessel group, which is only 2.2%. Figure 3.2 confirms that every region reveals a similar composition of the three different size groups. This is understandable, as small fishing vessels are more economical, regardless of their safety performance and low catch capacity (Utne, 2008).

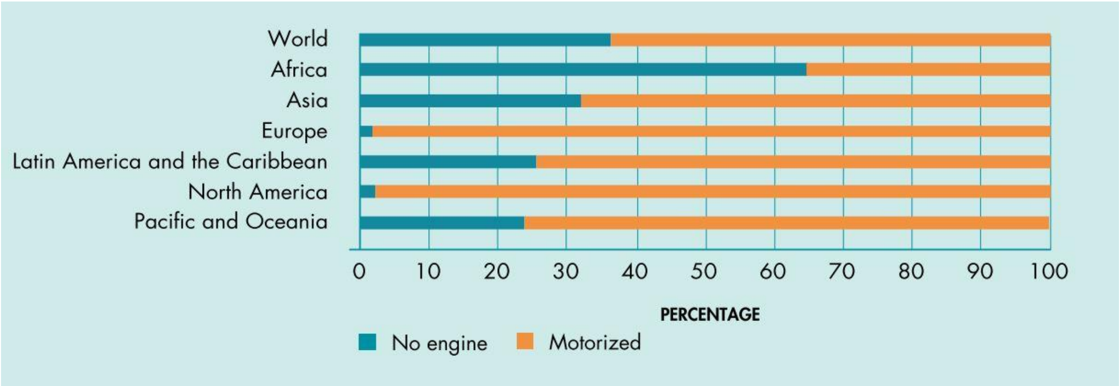


Figure 3.1 Composition of motorised and non-motorised fishing vessels
(FAO, 2016)

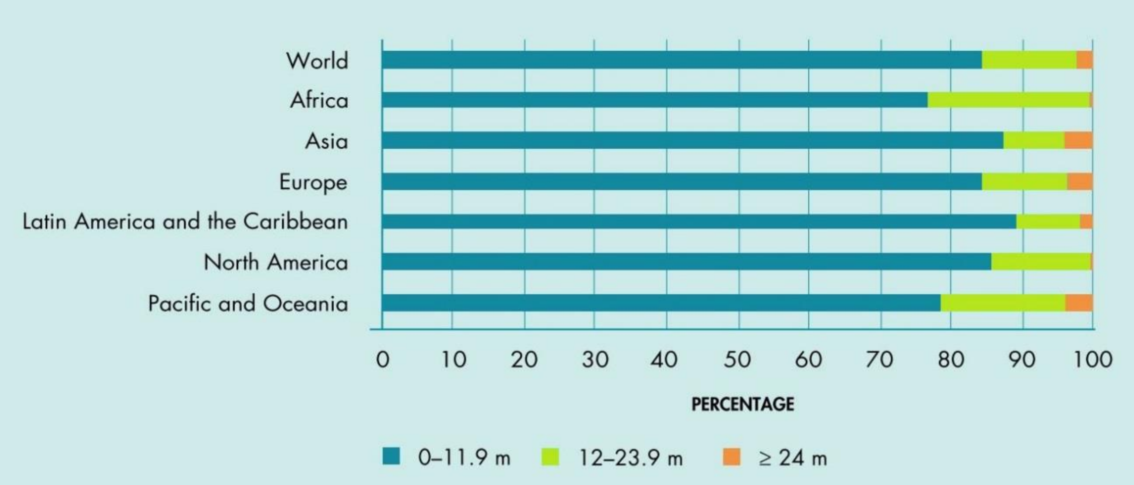


Figure 3.2 Size distribution of motorised fishing vessels
(FAO, 2016)

According to the FAO (2016), there is a disparity in the data from the FAO and International Maritime Organisation (IMO) concerning the large vessels group. Whilst the FAO recorded 64,000 units, the IMO documented only 23,000 units. This indicates that numerous fishing vessels remain unreported and even unregistered due to a lack of information and the poor quality of reporting at the national level. The same situation most likely occurs with the smaller vessels group as well, therefore, their actual numbers are almost certainly much higher than the published version. The gap between these two data sets needs to be addressed as it huge implications for the estimation of fishing effort and energy use in fishing.

3.2.2 Fishers

A global estimation in 2014 indicated that 37.8 million people was engaged in fishing activities, either as full time, part-time or seasonal fishers. Similar to fishing vessels, most of the fishers are concentrated in Asia which made up 78.4% of the total, followed by Africa (14.2%), Latin America and the Caribbean (5.5%), with the remaining regions accounted for less than 2% in total (Table 3.1). The dispersion pattern is aligned with the continent-based distribution of the world's population published by the Population Reference Bureau (2014), except for the fact that in the global population rank, Europe was in the third position, which is slightly higher than Latin America and the Caribbean.

Furthermore, considering the distribution of the vessel's population, the number of crew per fishing vessel in the three regions with the highest number of fishers, is two times higher than in the other regions, meaning that the fishing sector is labour intensive in

Asia, Africa, and Latin America and the Caribbean. From the socio-economic perspective, the higher employment rate in the fisheries sector will have beneficial implications, as it contributes to reducing the unemployment rate.

3.2.3 Fish resources and fishing areas

Generally, the status of fish resources can be defined into three categories, specifically, overfished, fully fished, and under-fished. Overfished is when fish resources utilisation is at an unsustainable state, fully fished is when utilisation is at the maximum sustainable limit and under-fished indicates that exploitation is below the sustainable yield. According to the FAO (2016), the status of the world's fish stocks in 2013 was 31.4% overfished, 58.1% fully fished and 10.5% under-fished. This means that most of the fish utilisation is either in a fully or underexploited state. In order to avoid these becoming overexploited, fishing operations must be managed properly.

Furthermore, for statistical, managerial, and jurisdictional purposes, the FAO has divided the oceans into 19 major fishing areas, as seen in Figure 3.3. According to Ye and Cochrane (2011), The Western Central, Northern Central and Southwest Atlantic, as well as the Mediterranean and the Black Sea are the areas where at least 50% of the fish stocks were in an unsustainable state. On the other hand, the percentage of unsustainable stocks in the Northeast and Southwest Pacific was only 10%. Figure 3.4 reveals the status of the fish stocks in different fishing areas based on a stocks assessment conducted in 2009.

Following the UNCLOS convention, every coastal state has exclusive rights to explore and utilise marine resources within 200 nm of the coastline. Beyond that is the high seas which every state has the right to fish. However, due to safety issues, vessels capacity, and licencing categories, most of the small vessels conduct fishing operations within the exclusive zone, with concentration in the territorial zone (within 12 nm) and contiguous zone (another 12 nm).

Considering the division of fishing areas (Figure 3.3) and the status of fish stocks (Figure 3.4), it can be said that most of the fishing areas around Africa were in an alarming state. In contrast, Oceania is surrounded by fishing areas with a high percentage of sustainable fish stocks.

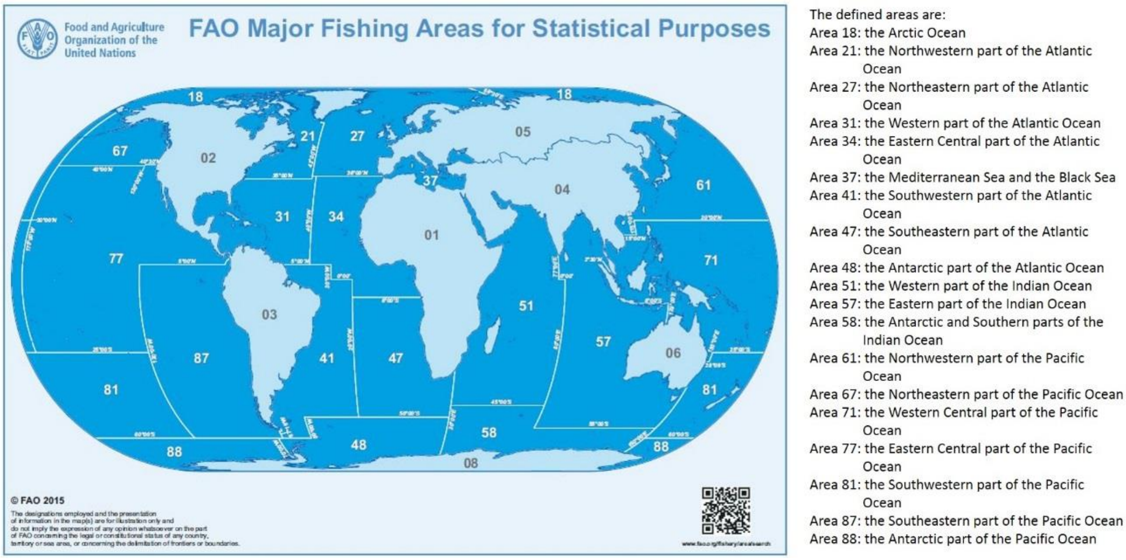


Figure 3.3 FAO major fishing areas
(FAO, 2015a)

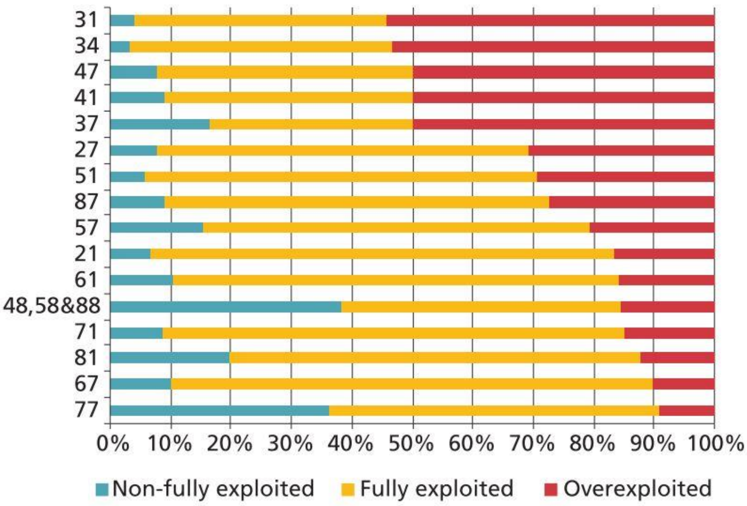


Figure 3.4 Status of the world's fish stocks
(Ye and Cochrane, 2011)

3.2.4 Fishing productivity

In 2014, it was reported that global fish production from capture fisheries was 91 million tons, which was led by Asia with a 55% contribution, followed by Europe and Latin America and the Caribbean, which contributed 15% and 12% respectively (Table 3.1). However, based on the vessels productivity, it can be seen that the most productive fishing operation was found in Oceania, which in fact contributed only 1% of the world's catch. On average, at least 150 tons of fish were landed annually per fishing vessel, which was 10 times higher than productivity in Asia, the leading continent. Furthermore, as fishing vessels in Europe employ a smaller number of people, the most productive fishers were European and Oceanian who caught 39 and 33 tons of fish per year, respectively. Once again, the number was significantly higher than Asian and African fishers. Thus, it can generally be concluded that fishing vessels operating in Oceania and Europe are significantly more productive than other regions.

The high level of fishing productivity in Oceania and Europe might be caused by prodigious fish abundance. The connection between Figures 3.3 and 3.4 demonstrates that Oceania and most of Europe are surrounded by fishing areas with healthy fish stocks. Furthermore, the fact that less vessels are operated in both areas might reduce the fishing pressure and increase the possibility of a fishing vessel catching more fish. Finally, the role of onboard technology also undeniably affects productivity. Fishing vessels from major producers in countries such as Australia, New Zealand, Spain, Norway, Denmark and Sweden are primarily equipped with fish finders, winches, and navigation systems which support the fishing process.

3.3 State of fishing vessel operations in Indonesia

The statistics of Indonesian capture fisheries is annually published by the Directorate General of Capture Fisheries (DGCF) – MMAF. The latest publication used in this thesis is Capture fisheries statistics 2015 (DGCF, 2015), as summarised below.

3.3.1 Fishing vessels

In 2014, the number of fishing vessels operating in marine waters was approximately 625,600 units. The Indonesian statistics categories fishing vessels based on power and tonnage which is presented in Figure 3.5. It should be noted that the diagram only shows the percentage of fishing vessels operating in marine waters. The figure reveals that non-powered, outboard, and inboard vessels are almost evenly distributed. However, when looking into the composition of inboard vessels, this group is dominated by 5 GT vessels or less, which made up 24.5% of the total inboard powered vessels.

Within the outboard powered group, no categorisation has been made. Even though most of the outboard vessels are small vessels, some of the medium fishing vessels are also powered by outboard engines. According to Wibawa (2016), 1 to 3 outboard engines are used as the main power source for 18 metres length fishing vessels in East Java, Indonesia, specifically Muncar and Brondong.

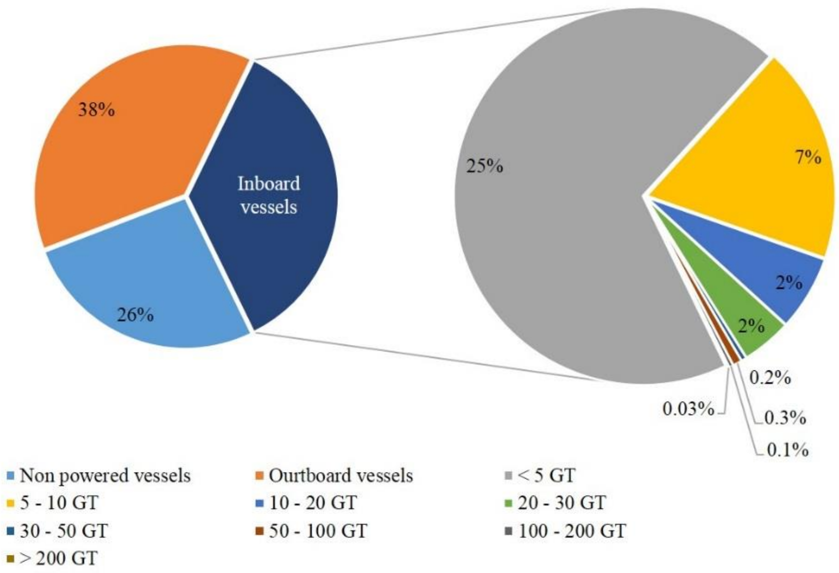


Figure 3.5 Composition of fishing fleets in Indonesia
(DGCF, 2015)

The number of motorised vessels has gradually increased since 2004. Furthermore, in order to optimise the use of fish resources, the Indonesian government has committed to developing the national fishing fleet by providing a motorised fishing vessel grant for fishers. Since its establishment in 2010, this programme is ongoing and at least one thousand fishing vessels ranging from 3 GT to 120 GT have been distributed throughout the country (Kiara, 2014; Grahadyarini, 2017).

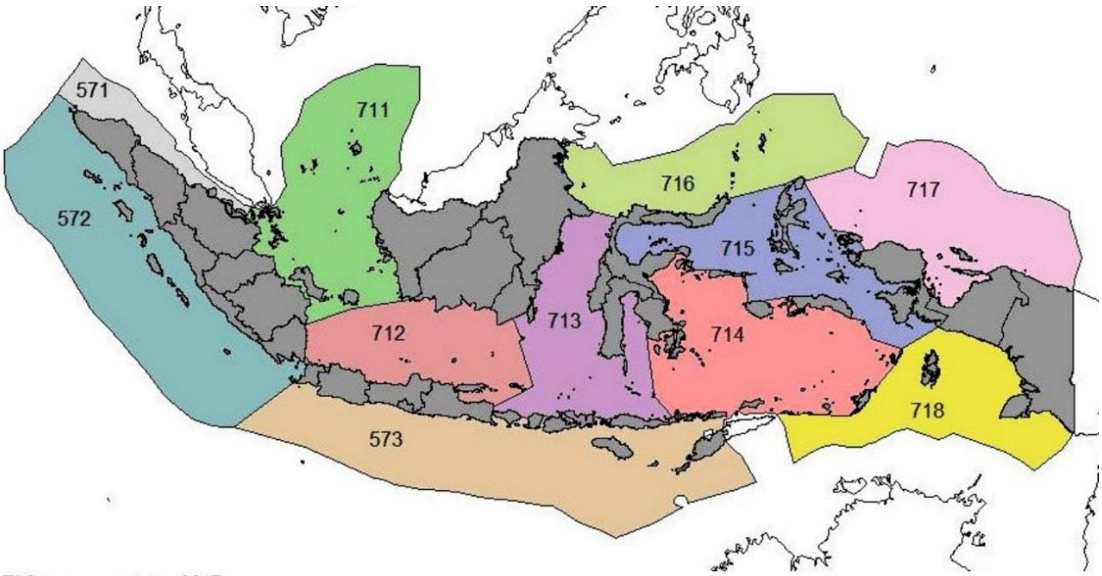
3.3.2 Fishers

In 2015, the number of fishers in Indonesia was approximately 2.2 million, including full-time (60%), part-time (26%), and seasonal fishers (14%). If it is divided by the number of fishing vessels, the average fishers per vessel is 4 people, which is significantly lower than the average for Asia. In fact, the number of crew on Indonesian fishing vessels vary from 1 to 25 people per fishing vessel, depending on the size and type of the fishing vessel and the gear used.

The number of fishers had declined in the previous 10 years. However, the percentage of full-time fishers had increased, which indicates that more people rely on fishing activities, despite it being a low-income and high-risk job.

3.3.3 Fish resources and fishing area

As depicted in Figure 3.3, Indonesia lies between two major fishing areas, 57 and 71. Moreover, Indonesian waters are also divided by the government into 11 fishing areas. According to the MMAF (2017b), the potential yield of the capture fisheries in 2017 was 12.5 million ton/year. Figure 3.6 shows that overfishing is found in each area with different fish stocks. Squid has been overfished in most of the fishing areas, however, the vast majority of demersal fish remains sustainable.



Fish resource status 2017

Fish resources	571	572	573	711	712	713	714	715	716	717	718
Small pelagic	0.8	0.5	1.5	1.4	0.4	1.2	0.4	0.9	0.5	0.7	0.5
Large pelagic	0.5	1.0	1.1	0.9	0.6	1.1	0.8	1.0	0.6	1.0	1.0
Demersal fish	0.3	0.6	0.4	0.6	0.8	1.0	0.6	0.2	0.5	0.4	0.7
Coral fish	0.3	0.3	1.1	1.5	1.2	1.3	0.8	0.3	1.5	0.9	1.1
Shrimp	1.6	1.5	1.7	0.5	1.1	0.5	0.4	0.8	0.5	0.5	0.9
Lobster	1.3	0.9	0.6	0.5	1.4	1.4	1.7	1.3	0.8	1.0	1.0
Crab	1.0	0.2	0.3	1.1	0.7	0.8	1.6	1.2	0.4	0.9	0.9
Swimming crab	0.9	0.5	1.0	1.2	0.7	0.7	0.8	1.0	0.5	1.2	0.8
Squid	0.6	0.4	1.1	1.8	2.0	1.2	1.0	1.9	1.4	1.1	1.3

Underfished Fully fished Overfished

Figure 3.6 Major fishing areas in Indonesia and the fish stocks status (MMAF, 2017)

3.3.4 Fishing productivity

As the second largest fish producer in the world, Indonesia contributed roughly 7% of global fish production for the capture fisheries sector in 2014. The vast majority was landed from marine waters, which accounted for 93% of national production. According to the DGCF (2015), fish production had increased over the last 10 years from 4.6 million tons in 2004 to 6.4 million tons in 2014. The government set a target of up to 7.8 million by the end of 2017 (Berita Satu, 2017).

By considering the number of fishing vessels and fishers, it can be roughly estimated that in 2014, productivity was 9.6 tons/vessel and 2.7 tons/fisher. Compared to the Asian average (Table 3.1), it can be seen that Indonesian fishing vessels were less productive, although a better performance was shown in relation to the fisher.

3.4 State of fishing vessel operations in Palabuhanratu

The statistics of Palabuhanratu fisheries is annually published by PPN Palabuhanratu. The latest version summarised in the following paragraphs is Fisheries statistics 2015 (PPN Palabuhanratu, 2015).

3.4.1 Fishing vessels

In 2015, the number of fishing vessels based in Palabuhanratu fishing port was 696 units consisting of inboard vessels (36%) and outboard vessels (64%) ranging in size from 2 GT to more than 200 GT. The fleet is composed of eight different types of vessel, specifically, longliner, troll liner, purse seiner, lift netter, trammel netter, gillnetter, handliner, and pelagic Danish seiner. The last three types are outboard vessels, whilst the remainings are inboard vessels, except gillnetters which consist of both inboard and outboard vessels. The composition of the fishing fleet in Palabuhanratu fishing port is presented in Figure 3.7.

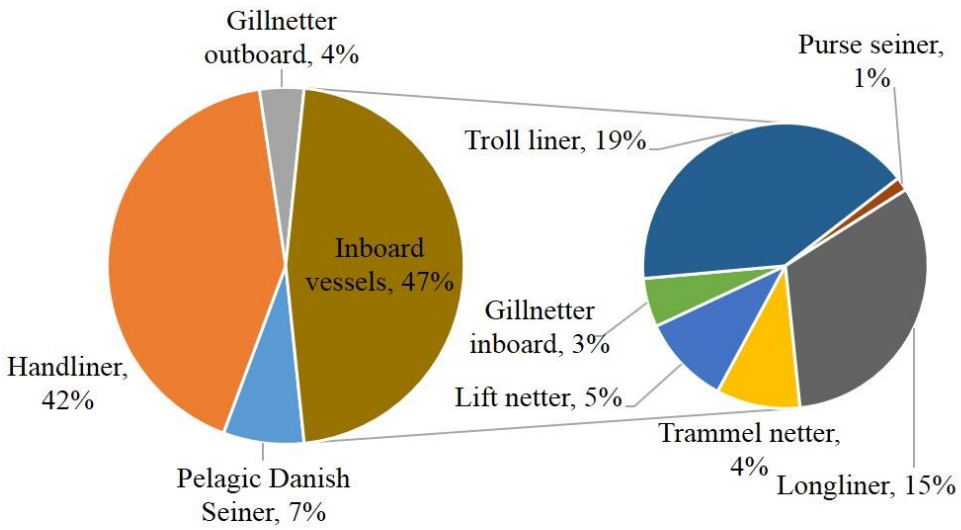


Figure 3.7 Composition of the fishing fleet in Palabuhanratu (PPN Palabuhanratu, 2015)

3.4.2 Fishing community

At least 4.8 thousand people are engaged in fishing-related activities as fishers, fishing vessel owners, fish sellers, fish processors, suppliers, and other supporting businesses, such as shipbuilders, engineers, and port workers. The fisher is the person who is directly involved in the fishing operations, whilst other groups conduct secondary activities prior to and after the fishing process. Figure 3.8 shows that fishers are the principal occupation, comprising 66% of the community. Information regarding occupational status is not available, however, according to the port authority, most work as full-time fishers.

A report issued by The Government of Sukabumi Regency (2016) and The Government of Palabuhanratu District (2016), explains that the proportion of people working in the fishing sector is approximately 16% of the region's population and 24% of the population is in the economically productive age (between 15-64). Furthermore, considering male domination in fishing activities, fishers accounted for 30% of males within the productive age. This fact confirms that the fishing sector plays a significant role in employing members of the community in Palabuhanratu.

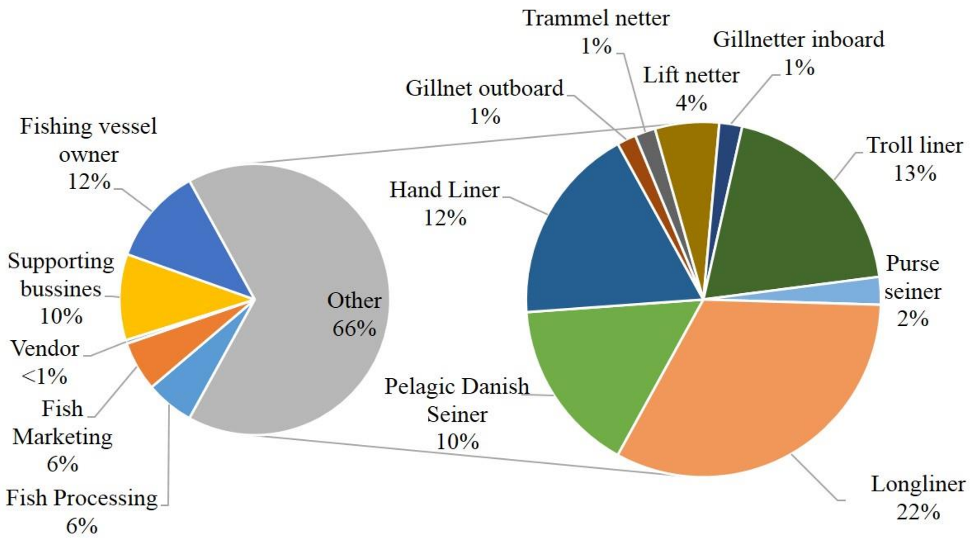


Figure 3.8 Composition of the fishing community in Palabuhanratu (PPN Palabuhanratu, 2015)

3.4.3 Fish resources and fishing areas

Palabuhanratu Bay is typical of the southern coast of Java Island being characterised by strong waves. The bay also has a steep seabed, which reaches a depth of 200 metres within a few nautical miles (nm) of the coastline. The centre of the bay is even deeper being more than 2000 metres in depth. The longliners, troll liners, purse seiners, and inboard gillnetters conduct their fishing operations beyond the bay up to 8º S or 9º S, whilst the smaller vessels including handliners, pelagic Danish seiners, outboard gillnetters, trammel netters, and lift netters are concentrated in the shallow waters of the bay (Figure 3.9). The furthest fishing grounds for small vessels are in the waters off Binuangeun and Ujung Genteng.

As shown in Figure 3.6, the major fishing area for fishing vessels based in Palabuhanratu is 573, which shows a difficult situation, as most of the fish resources have been over exploited. The signs of overfishing is also confirmed by the fishers who are aware that fishing operations have become less productive recently and certain species have disappeared. The fact that the status of the fish stocks is at an unsustainable level requires immediate action to reduce the fishing effort. However, it will be challenging, seeing as the fishing sector is economically crucial in Palabuhanratu.

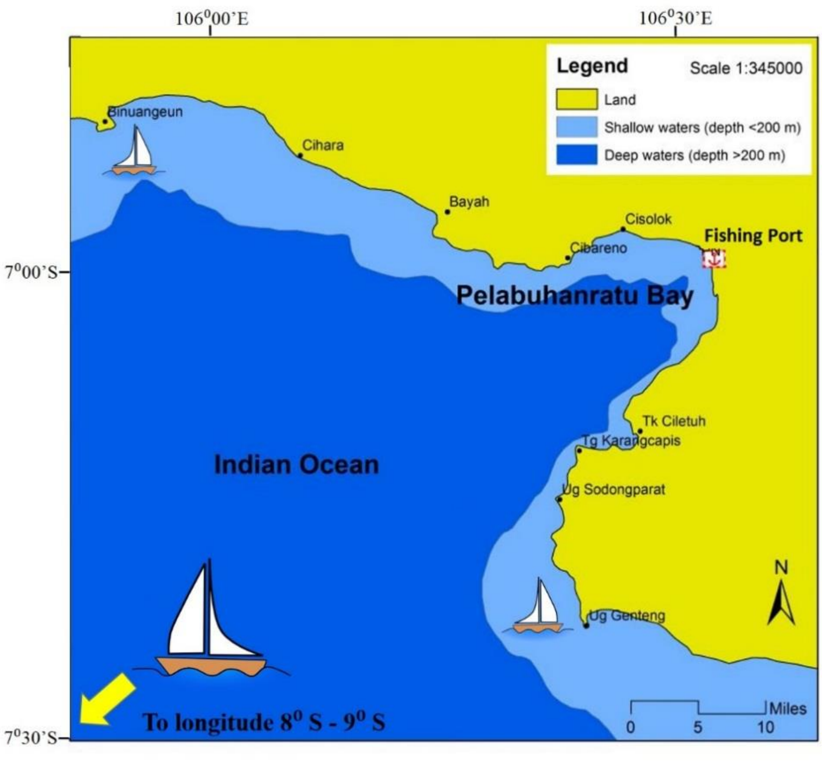


Figure 3.9 Fishing grounds for fishing vessels based in Palabuhanratu (Dishidros, 2004)

However, there is also a common belief among the small-scale fishers that the decrease in productivity is caused by the operation of large fishing vessels at the mouth of the bay, which use fish aggregating devices (FAD), and thus prevent the fish from migrating into the bay. Furthermore, the fishing zone 573 covers a large area which consists of many species. According to Iranawati *et al.* (2016), fish stock cannot be generalized as genetic closeness is required in order for species to breed, therefore, further investigation of the status of fish stock in Palabuhanratu is necessary in order to perform the best management action.

3.4.4 Fish production

The total amount of fish production at the fishing port in 2015 was roughly 9 million tons. This was one million lower than fish production in 2014, which reached 10 million tons. The largest contribution was from tuna, which accounted for at least 80% of the landed catch. Figure 3.10 shows the composition of fish production in 2015 excluding the tuna caught by longliners. The figure reveals that troll liners and lift netters were the major contributors to fish production. Whilst the main catch of troll liners was large pelagic fish such as tuna and marlin, lift nets primarily catch smaller fish such as anchovies, ponyfish, and small shrimp.

Regarding the productivity of fishing vessels and fishers, the longliner is again leading the chart by landing 70 tons/year/fishing vessel and 7 tons/year/fisher. It is followed by the lift netter which on average is capable of producing 19 tons/year/vessel and 3 tons/year/fisher. As seen in Table 3.2, the lowest productivity is derived from handliner, which lands 0.3 tons/year/vessel and 0.2 tons/year/fisher.

After landing, catches go to various destinations including being sold to the local market or restaurants, to local fish processors and to wholesalers or companies that supply both national and international markets. Fish processing houses located in the region typically produce a variety of products including fish balls, salted fish, boiled fish, and shrimp paste. Cold storage is provided in the fishing port to store fish prior to the distribution to other cities and countries. Cold storage is normally used for storing primary seafood products, such as tuna, bullet tuna, skipjack, and hairtail fish.

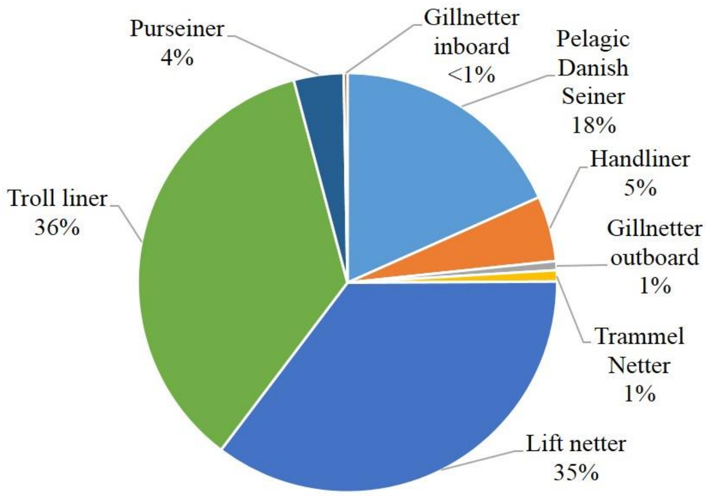


Figure 3.10 Distribution of landed fish in Palabuhanratu, excluding tuna (PPN Palabuhanratu, 2015)

Table 3.2 Annual fishing productivity in Palabuhanratu

Fishing fleet	Fishing productivity	
	tons/year/vessel	tons/year/fisher
Longliner	69.9	7.0
Lift netter	18.9	3.3
Purse seiner	13.5	0.8
Pelagic Danish Seiner	6.3	0.6
Troll liner	4.7	1.0
Gillnetter inboard	1.4	0.4
Trammel Netter	0.5	0.3
Gillnetter outboard	0.4	0.2
Handliner	0.3	0.2

Source: (PPN Palabuhanratu, 2015)

3.4.5 Weather condition and the fishing seasons

As a tropical country, the temperature in Indonesia is relatively constant throughout the year. However, Indonesia experiences two seasons, a dry season (April-September) and a rainy season (October-March) owing to monsoons passing through the region. Monsoons periodically blow from the southeast and northeast of Indonesia and change the wave and current pattern of the ocean, which according to Eveson *et al.* (2015) affect fish migration. In Indonesia, monsoons form four different seasons namely west monsoon (October-March), east monsoon (April-September), and two transitional seasons (March-April and September-October) which affect fishing patterns, especially in coastal areas (Nontji, 2005).

Figure 3.11 shows the typical weather pattern in Palabuhanratu which was plotted based on data from 2009 to 2015. When the east monsoon blows from April, the rainfall

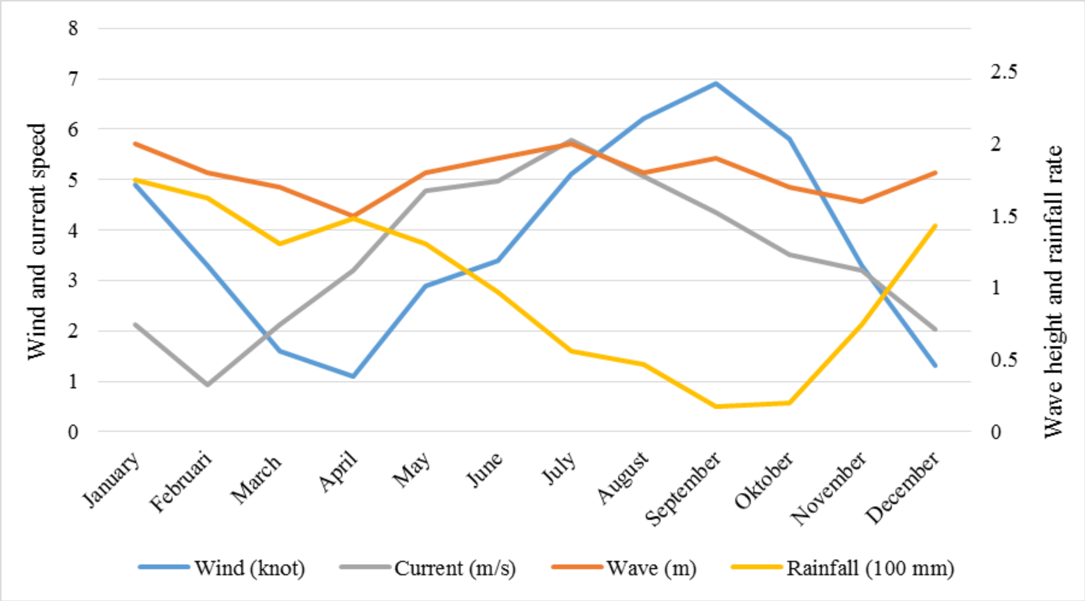


Figure 3.11 Weather conditions in Palabuhanratu Bay
(Meteorological Climatological and Gheophysical Agency (MCGA), 2016)

decreases and the region experiences a local dry season. The sea condition gradually gets rougher and reaches its peak during the transitional period to the west monsoon, i.e. between September and October. Subsequently, throughout the west monsoon, the rainfall increases and peaks in December and January, followed by an increase in wind speed and waves when the sea conditions are challenging. During the transitional period to the east monsoon, between March and April, the sea weather gradually becomes calmer, whilst the rainfall remains high.

Monsoon activities affect the fish pattern in Palabuhanratu Bay. Throughout the year, the fishers experience peak, moderate and low seasons, which define the fishing effort, the catch and their incomes. Generally, the peak season lasts for 3 months from August to October, followed by a low season from November to March and a moderate season from April to June. However, each fishing operation will have their own seasons depending on the abundance of the particular fish target.

3.5 Survey of the existing practices of selected vessels

In order to understand the fishing profile of SSFV in Palabuhanratu, the first fieldwork was conducted from September to November 2015. Not all SSFVs operated in Palabuhanratu were surveyed, yet the survey focused on four selected operations, which are dominant in the region. Furthermore, the profile of fishing operations was mapped by collecting statistics report, observing the fishing activities, and interviewing stakeholders involved in the fishing activities. The mapping includes the operational method, fishing attributes, the structure of the value chain, and the sharing system. The following paragraphs explain the rationale behind the selection, data collection, and the general mapping of each studied vessel.

3.5.1 Selected studies

According to Section 2.3.3, a SSFV is defined as a vessel which is 5 GT or less, traditionally operated in coastal waters and aimed at supplying local markets. Following that definition, five distinctive types of fishing vessel were included, specifically, pelagic Danish seiner, handliner, trammel netter, lift netter, and gillnetter with outboard engine. However, this study focuses on the first four vessels, excluding the gillnetter, due the following reasons. Firstly, the gillnetter with outboard engine has great similarities to the handliner, even though each one employs different fishing gear. Secondly, its population and contribution are relatively small compared to the handliners, and lastly, during the fieldwork, it did not actively operate due to the bad weather.

The four studied vessels represent different types of operation. Based on the fishing gear operational method, there are active and passive fishing, and based on the fish target, there are pelagic and demersal fishing. In active fishing, the vessel moves to operate the gear, whilst in passive fishing, the vessel waits when the gear is being operated. Furthermore, pelagic fishing captures the fish near the surface, and demersal fishing captures the fish near the seabed. Figure 3.12 shows the classification of each studied vessel into different operational methods.

	Active fishing	**Passive fishing**
Pelagic fishing	Pelagic Danish seiner	Lift netter
Demersal fishing	Trammel netter	Handliner

Figure 3.12 Classification of studied vessels based on the operational method

Respondents involved in this study were stakeholders who represent the four studied vessels. Additionally, stakeholders were further classified into four groups: workers, value chain actors, local community, and society. “Workers” refers to persons who are hired to run and manage fishing vessel operations and this includes fishers, skippers, and port-based workers. The port-based worker is a person working for the vessel, but do not go to the sea. “Value chain actors” are persons who are involved in fishing-related business including vendors, vessel owners, fish seller, fish buyers and second-hand goods buyers. The fish seller is a person who sell the fish from the vessel to the buyers. “Local community” refers to persons who are directly and indirectly influenced by the fishing activities, such as fishers’ wives and young people. “Society” comprises influential figures and local government officers who are concerned with the development of fishing activities in Palabuhanratu.

3.5.2 Data collection

Three methods of data collection were used, which are statistics reports, observation, and interviews as described below.

1. Statistics reports

   Statistics reports from selected studies from 2009 to 2015 were used for analysing the performance of the fishing operations and developing the model. Furthermore, they were used for validating input variables applied in this study.

2. Observations

   In order to collect information concerning the existing practices, two types of observation were conducted, these being one-day and one-month observations. A one-day observation is an on-board activity for gathering the actual data related to an operational method such as speed, fuel consumption, fishing hours, and productivity. Various equipment was used to collect the data, such as GPS, a tachometer, and a camera. One-month observations record the fishing inputs and outputs for each fishing vessel over a month. Both one-day and one-month data will be used for modelling the fishing vessel operation, which is detailed in Chapter 4. The observations were only conducted on four vessels representing each selected type and the specification is provided in Appendix C.

3. Interviews

Respondents were chosen based on their involvement in the fishing community, as summarised in Table 3.3. The role and distribution of representatives from each studied vessel is detailed in Appendix D. At least 152 respondents representing four fishing operations were questioned about the existing fishing practices using a range of questions relevant to their roles. Two type interviews were used to collect data, these being semi-structured and structured interview.

A semi-structured interview is an in depth conversation, and this was undertaken with 34 respondents. It was aimed at understanding the current fishing practices in detail. The interviews were conducted using open ended questions, which allowed the respondents to elaborate their answers. Examples of transcriptions from in depth interviews are provided in Appendix E. These are not verbatim transcriptions, hence, only the substantive conversation is included. The text is originally in Bahasa Indonesia, which has been translated into English.

The structured interview, on the other hand, was conducted with 118 respondents. Questionnaires consisting of 50 to 60 short questions with restricted answer choices were used to gather information regarding social aspects of fishing vessel operations. Examples of questionnaire results obtained from fishers, housewives, and youth groups are also provided in Appendix E.

Before the interviews, participants were informally asked about their agreement to participate in this research, including having their conversations recorded.

Table 3.3 Respondents involved in the survey

Stakeholders		**Interview method**	
		Semi structured	**Structured**
Workers	1. Fishers/Skippers	14	22
	2. Port-based workers		8
Value chains	1. Vendors		11
	2. Owners	10	8
	3. Sellers	4	
	4. Fish buyers		6
	5. Secon hand goods buyers		3
Society	1. Influential figures	3	
	2. The government	3	
Local community	1. Fisher's wives		30
	2. Youth		30
Total respondents		34	118

Considering the nature of the fishing community in Palabuhanratu, verbal consent was more appropriate than written consent, given that it might lead to misunderstandings. Interviews were conducted in Bahasa Indonesia, either at the fishing port or at respondents' homes depending on their preferences. Some interviews were not one-to-one as several participants randomly joined in, in the middle of the conversation.

The survey result presented in this section incorporates a general description, operational profile, fishing attributes, value chain, and sharing system related to each studied vessel. Fishing attributes refer to items attached to the operational of the fishing vessels, which include fishing inputs and outputs. The fishing input is the production factor to conduct the operation, such as the vessel itself, fishing gear, engine, and fuel. Meanwhile, the fishing output is the outcome of the operation, which is catch and income. Furthermore, it should be noted that not all data collected by means of the observations and interviews are presented here due to the connection with Chapter 4 and Chapter 5.

3.5.3 Pelagic Danish seiner

1. General description

   A pelagic Danish seiner is a vessel that operates a Pelagic Danish seine net (PD), and in this thesis, the vesel will be referred as PD vessel. According to the FAO (2003a), Danish seine is encircling gear which primarily consists of a conical bag net, two long wings and two long rope extensions. A typical PD vessel in Palabuhanratu is a 5 GT wooden boat powered by a 40 HP marine outboard engine. The vessel operates daily from dawn to dusk in the fishing areas located within 10-20 nm from the port. As the net is operated manually, the vessel is typically crewed by 10 – 15 fishers, including the skipper. Neither deck machinery or safety equipment are provided to support the operation. However, a car's inner tube is used as a boat to help the fisher control the net when it is being circled (setting tool), which can also be used as a life buoy. Figure 3.13 shows a typical PD vessel in Palabuhanratu. The illustration of the fishing method is taken from (FAO, 2003a).

2. Operational profile

   Figure 3.14 illustrates the fish catching process of the PD vessel. The engine is switched off only when the net is hauled. Once the fish are located, the setting process is started by anchoring the buoy, then encircling the fish with the net before returning to the anchored buoy. Shortly after, the whole net is hauled back onto the vessel with

Figure 3.13 A typical PD vessel in Palabuhanratu

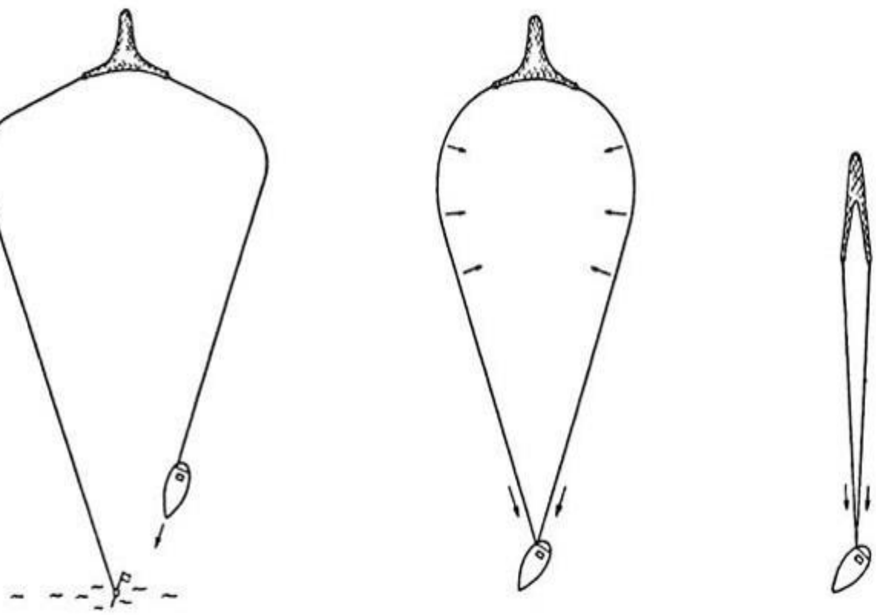


Figure 3.14 Fish catching process in the PD vessel
(Nédélec and Prado, 1990)

the fish are captured in the bag net. The vessel is required to surround the fish quickly, otherwise the fish will escape. Therefore, good manoeuvrability and speed are important features of a successful operation. The net can be operated both for pelagic and demersal fish depending on its construction. The one that is operated in Palabuhanratu is designed for pelagic fish.

During the operation, a PD vessel keeps moving to locate and catch the fish. Once the vessel arrives in the main fishing ground, the catching process can be conducted repeatedly depending on the fish abundance. Figure 3.15 depicts the operational profile of the PD vessel from leaving the port until returning back to the port.

3. Fishing attributes

Table 3.4 describes the fishing attributes to run a fishing operation using a PD vessel. The major investment consists of a vessel, fishing gear, and an outboard engine that can last for 20, 10, and 7 years respectively with regular maintenance. For fish storing, instead of using the space underneath the deck, fishers prefer to use a 200 litres plastic drum. Additionally, an ice block is used to keep fish fresh. On average, for the normal one-day trip, the vessel will carry approximately 60-90 litres of fuel and 1-2 ice blocks (@ 50kg), whilst the outcomes of the operation will fluctuate depending on the seasons.

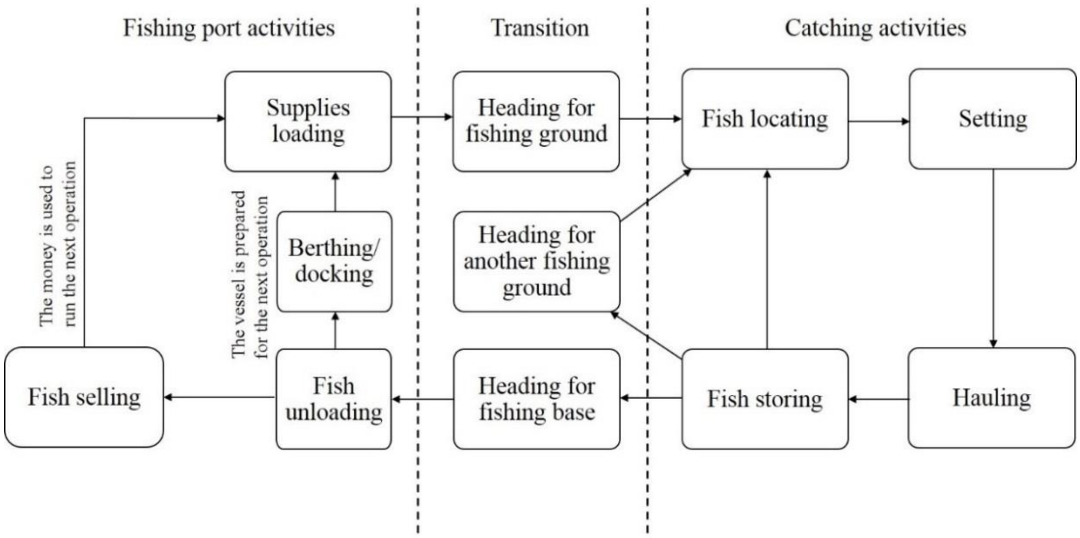


Figure 3.15 Operational profile of the PD vessel

Table 3.4 Fishing attributes of the PD vessel

Inputs			Outputs
Capital	**Maintenance**	**Supplies**	
Fishing vessel Engine Fishing gear Fish containers Fuel containers	Fishing vessel Engine Fishing gear	Petrol Lubricant Ice	Catch Revenue

4. Value chain and sharing system

Most of the owners hire a skipper to operate the vessel. In addition, they will employ at least three port-based workers who are responsible for engine and fishing gear maintenance and general tasks respectively. Whilst the skipper only works for one vessel, the workers can work for more than one vessel. Figure 3.16 shows the value chain of the PD fishing. When the vessel arrives at the port, the owner takes over the chain by selling fish to the fish seller. However, in practice, the seller will take the fish from the vessel directly with the owner's permission and continue the chain. After receiving money from the seller, the owner will divide the revenue according to the common sharing system described in Figure 3.17. The owner pays the operational cost, hence, when the trip does not make any profit, he will bear the loss.

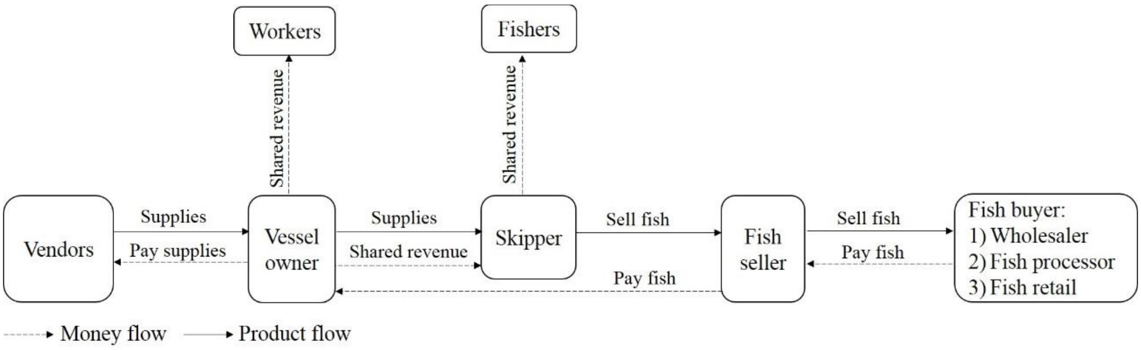


Figure 3.16 Value chain in the PD vessel

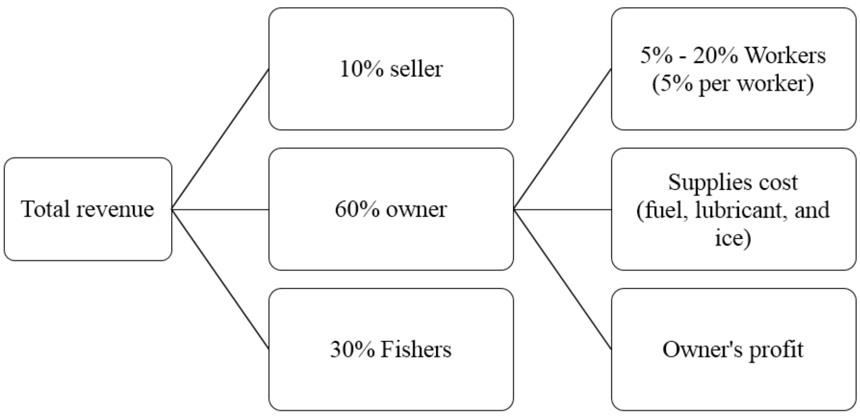


Figure 3.17 Sharing system in the PD vessel

3.5.4 Trammel netter

1. General description

A trammel netter operates a trammel net (TN), and in this thesis, it is denoted as the TN vessel. A TN vessel is typically a 9 metre long wooden vessel, powered by a 24 HP – 30 HP inboard engine. The tonnage is approximately 4 GT. Crewed by 3-4 people, the vessel conducts daily fishing trips during the day. According to the FAO (2001b), a TN consists of a nylon net with three layers, which has floats attached to the upper side and weights on the bottom. It is deployed on the seabed to catch ground fish and crustaceans. Figure 3.18 shows the typical TN vessel in Palabuhanratu.

2. Operational profile

Basically, a TN vessel operates the net passively by transversely stretching the net under the water to form a wall. However, in Palabuhanratu, a TN vessel principally conducts active fishing by encircling the net at a low speed. The net is circled in order to sweep the seabed for roughly 30 – 60 minutes. Therefore, it requires a powerful engine.

Figure 3.18 A typical TN vessel in Palabuhanratu

An active operation is performed during the rainy season, in the fishing ground located about 20-40 nm from the port. A passive operation is conducted only when the shrimp, as its main target, is at low season, which normally falls during the dry season. During that time, the net will be deployed on the seabed and left for a minimum of 12 hours. Figure 3.19 shows the catching process for both passive and active operations. The fishing ground is usually within 5 nm from the fishing port, consequently, the vessel conducts 2 return trips to set and haul the net. When o perating at further fishing grounds, the trip is usually last for at least 5 days, yet the vessel will temporarily berth at the nearest quay and keep conducting one-day fishing trips from that point. Figure 3.20 displays the working pattern for both operations.

3. Fishing attributes

Table 3.5 shows the fishing attributes of the TN vessel. For an active operation, a trammel netter carries about 20-30 litres of diesel fuel and a ½ ice block (25 kg), whilst for a passive operation, typical supplies are 15-20 litres of fuel with the same amount of ice.

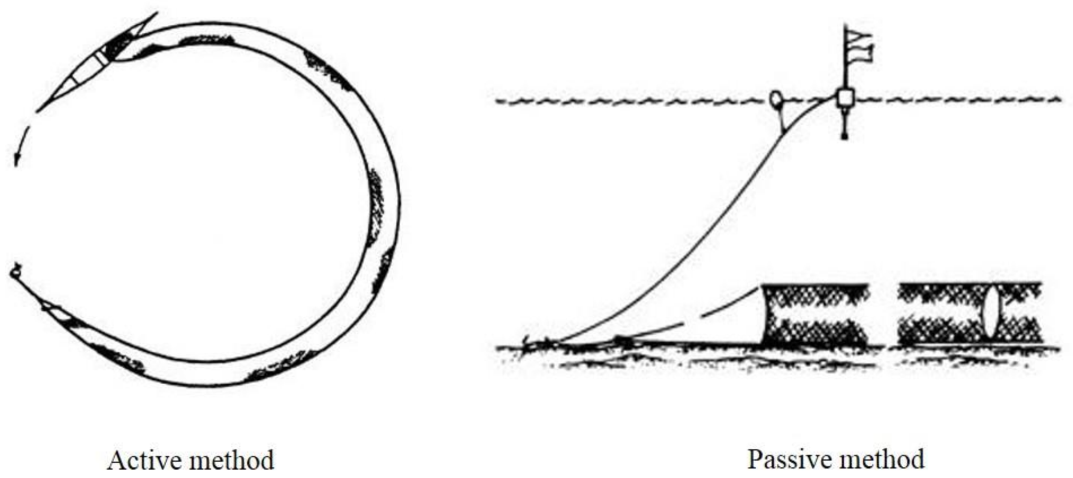
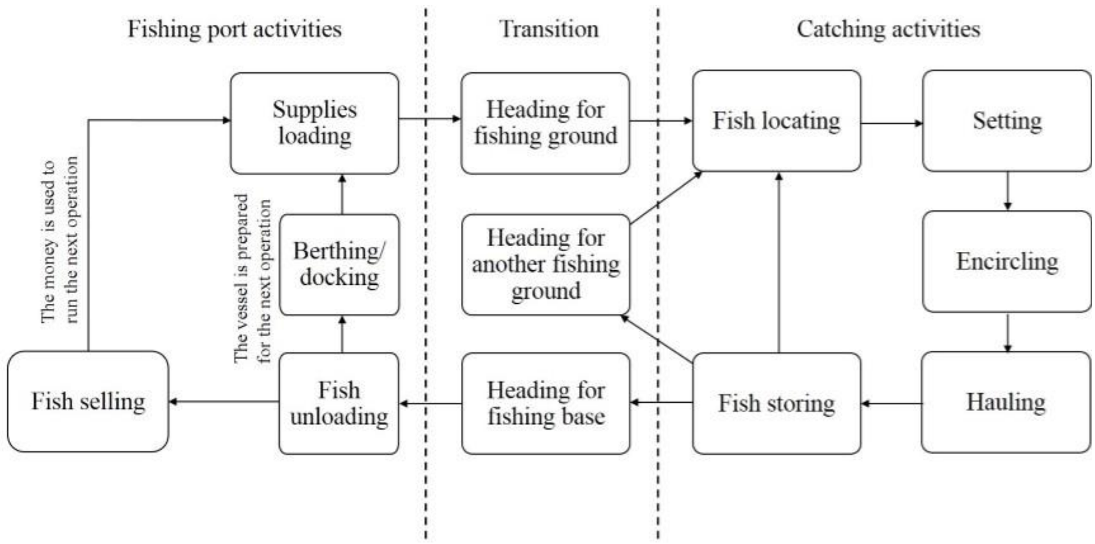
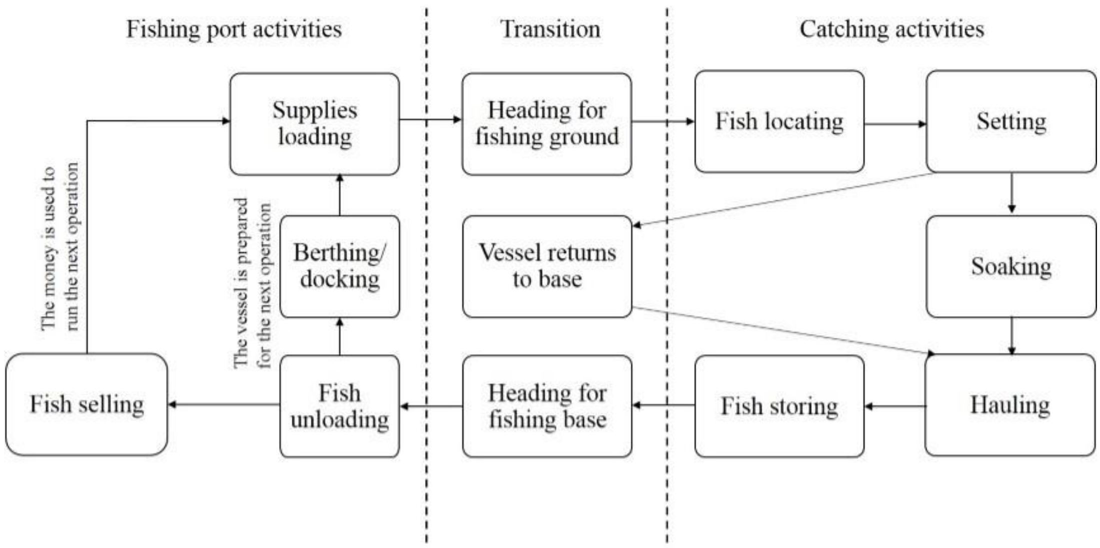


Figure 3.19 Fish catching process in the TN vessel
(Nédélec and Prado, 1990)



a. Active operation



b. Passive operation

Figure 3.20 Operational profile of the TN vessel

Table 3.5 Fishing attributes of the TN vessel

Inputs			Outputs
Capital	**Maintenance**	**Supplies**	
Fishing vessel	Fishing vessel	Diesel fuel	Catch
Engine	Engine	Ice	Revenue
Fishing gear	Fishing gear		
Fish containers			
Fuel containers			

4. Value chain and sharing system

In TN fishing, once the vessel arrives at the port, the fish will be sold to any buyer who offers a good price, as seen in Figure 3.21, no seller is involved in the value chain. Furthermore, most of the skippers are actually the owners of the fishing vessels. In the case of the skipper is employed by the owner, he will be given the responsibility to sell the catch.

Figure 3.22 confirms the sharing system in TN fishing. It can be noticed that after the operational cost is deducted from the total revenue, the owner takes 50% of profit alone, whilst another 50% is equally shared amongst the fishers (including skipper). The owner receives the largest portion as he is responsible for the fishing gear and engine replacement which occurs at least every 2-3 months and 3 years respectively.

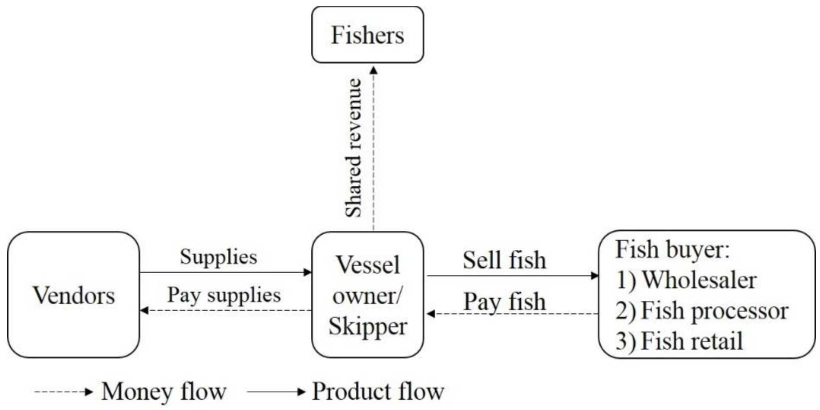


Figure 3.21 Value chain in the TN vessel

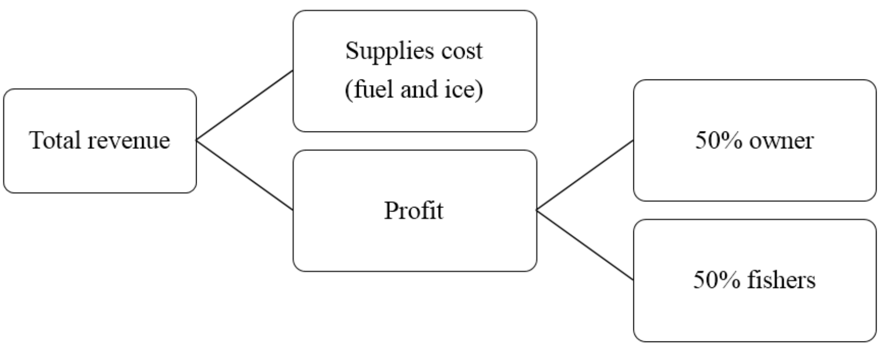


Figure 3.22 Sharing system in the TN vessel

3.5.5 Handliner

1. General description

A handliner refers to a vessel operating a handline (HL), which will be abbreviated as HL vessel. A typical HL in Palabuhanratu is a 2 GT fibreglass hulled vessel with a length of between 7-9 metres and powered either by a single 15 HP engine or two 4-5 HP outboard engines (Figure 3.23). Whilst the first engine is a marine outboard engine, the latter are typically modified multipurpose engines. Crewed by 1 or 2 people, the vessel operates predominantly during the night, on a daily basis. A daytime operation is sometimes performed depending on the abundance of the fish target. The main target of HL fishing in Palabuhanratu is hairtail fish which inhabit the waters just above the seabed.

Figure 3.23 A typical HL vessel in Palabuhanratu

2. Operational profile

HL is a simple fishing gear consisting of lines and baited hooks which can be operated either in a fixed position or from a vessel which is drifting or anchored. During the catching process, the vessel is anchored, the engine is switched off and the gear is lowered to a certain depth until the fish are hooked (Figure 3.24). With this fishing method, good stability is the main requirement for the vessel in order to support the fishing operations optimally. Figure 3.25 shows the operational profile of the HL vessel. As the gear is operated passively, the vessel is only motoring during transition activities.

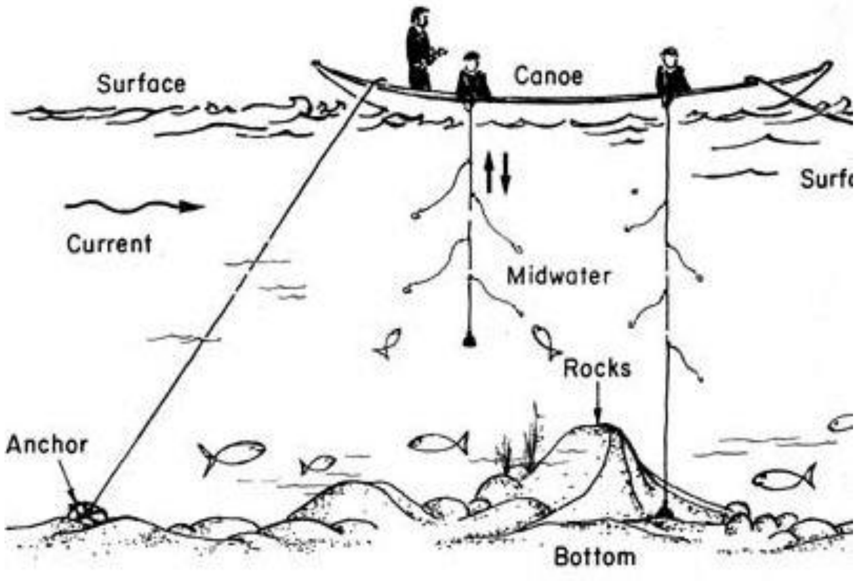


Figure 3.24 Fish catching process in the HL vessel
(Bjarnason, 1992)

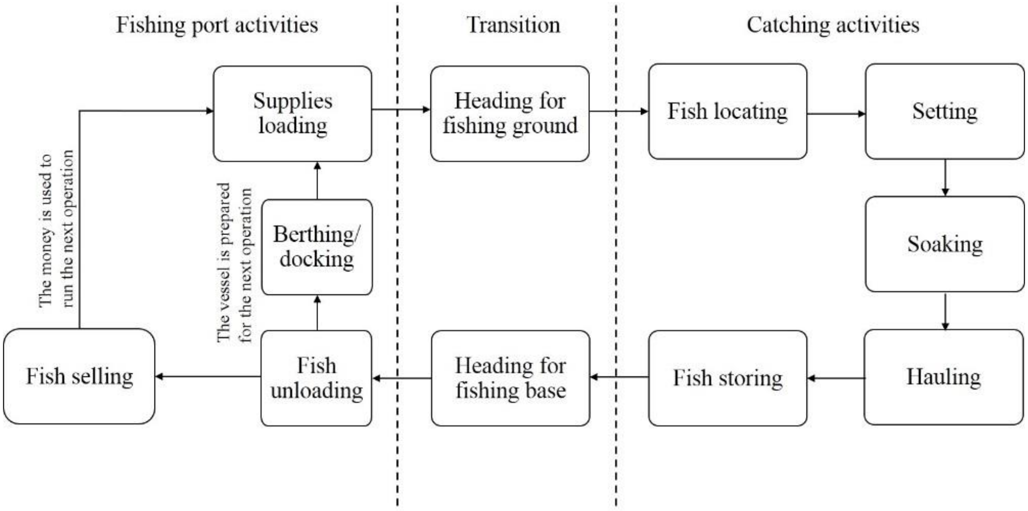


Figure 3.25 Operational profile of the HL vessel

3. Fishing attributes

The capital component of the HL vessel is almost similar to a PD vessel, except the lamps that are used for both lighting and attracting fish are installed on the vessel. Furthermore, the fishing operation requires a 3 kg of fish as bait. Additionally, about 5-10 litres of fuel, a ½ block of ice (25kg) are brought for a typical one-day trip. Table 3.6 present the list of fishing attributes for the HL vessel.

Table 3.6 Fishing attributes of the HL vessel

Inputs			Outputs
Capital	**Maintenance**	**Supplies**	
Fishing vessel Engine Generator Fishing gear Fish containers Fuel containers Lamps	Fishing vessel Engine Generator Fishing gear	Petrol Lubricant Ice Baits	Catch Revenue

4. Value chain and sharing system

A skipper plays an important role in HL fishing, as he is not only hired to run the vessel but also authorised to collaborate with the fish seller and employ a worker (Figure 3.26). The skipper can work alone or be accompanied by other fishers to work together. When arriving at the port, the fish seller takes over the responsibility of selling the fish to other parties. In contrast, the worker takes over the vessel and prepares for the next trip. Both worker and fish seller can work with more than one vessel.

In HL fishing, the fish seller and worker are part of the sharing system and receive a 10% and 5% fee (Figure 3.27). Furthermore, operational cost and profit are shared equally between skipper, owner, and other fishers (if applicable).

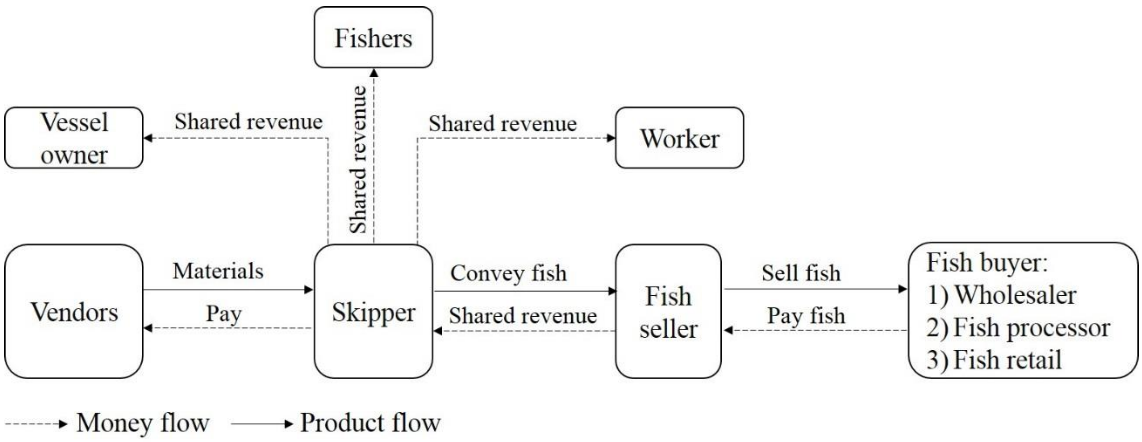


Figure 3.26 Value chain in the HL vessel

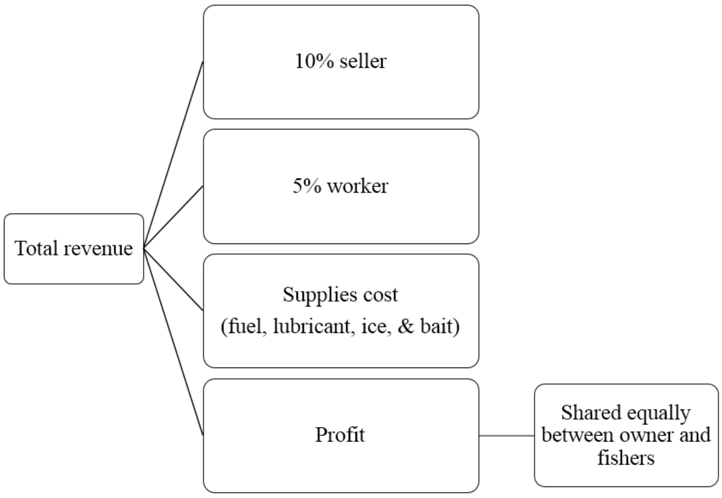


Figure 3.27 Sharing system in the HL vessel

3.5.6 Lift netter

1. General description

A lift net (LF) is a rectangle or bag shaped net with an upward facing opening, which is horizontally immersed at a certain depth. According to the FAO (2001a), three basic types of the LF can be identified, namely, portable hand lift nets, boat operated lift nets and shore operated stationary lift nets. The most common LF operations are boat operated and use lights to catch small pelagic species. In fact, LF fishing in Palabuhanratu are shore operated moveable lift nets which also employ lights to catch the fish. A vessel is used to serve the fishers accessing their LFs. Therefore, in this context, a lift netter consists of the vessel and 8–10 LFs which are installed on non-powered bamboo platforms and in this thesis, a lift netter will be referred as LF vessel, which comprises the ferry and the platforms.

The LF platform is approximately 9x9 metres and the working deck is about 2 metres above sea level. It is anchored within 5 nm from the fishing port and will repeatedly move following the fish abundance as well as current and wind directions. The boats are wooden-hulled vessels about 14 metres in length and the tonnage is approximately 5 GT. Figure 3.28 describe a typical ferry and platform used in LF operations in Palabuhanratu.

Figure 3.28 A typical LF vessel in Palabuhanratu

2. Operational profile

The fishing process is conducted during the night by 1 or 2 people per platform. Figure 3.29 illustrates the fish catching process in the LF vessel. The net is soaked for about 2-3 hours and lamps are used to attract the fish (Martasuganda, 2012).

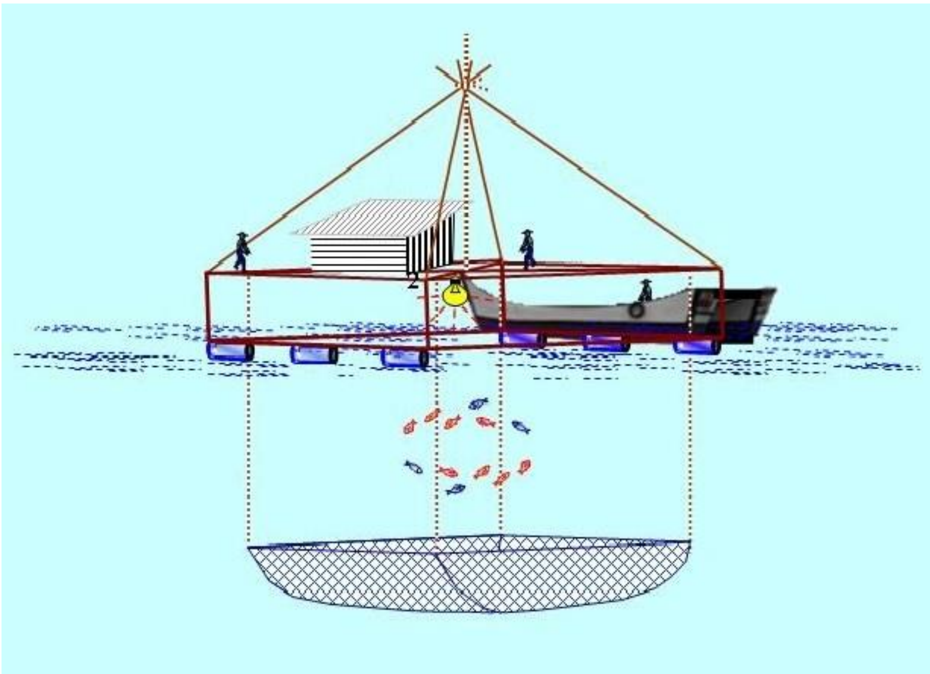


Figure 3.29 Fish catching process in the LF vessel (Martasuganda, 2012)

As the floating platforms are spread out over an area of water, the ferry is run to serve the fishers who operate the platforms and to move the platforms from one fishing spot to another. Due to the necessity to move the platforms, the ferry is primarily powered by a 100 HP marinised inboard engine. Crewed by 1 or 2 people, the vessels conduct a return trip in the late afternoon to shuttle the fishers to their platforms. The next morning, the vessel will pick up the fishers and take them back to the port. Figure 3.30 shows the operational profile of the LF vessel.

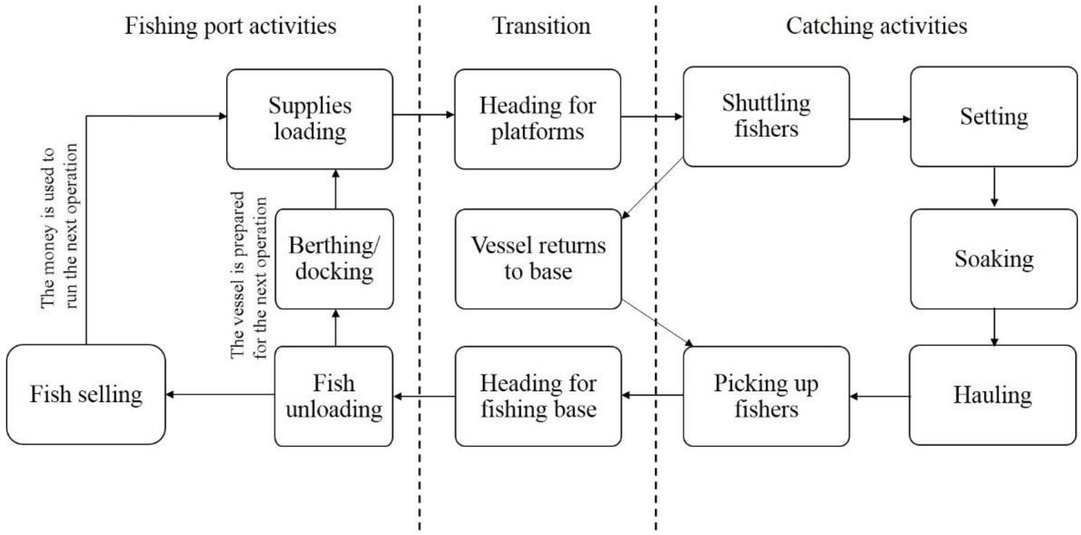


Figure 3.30 Operational profile of the LF vessel

3. Fishing attributes

An LF platform consists of a bamboo platform, a net, and other components, as seen in Table 3.7. Whilst the net is attached to the platform, the remaining equipment is portable, as the fishers carry them on each fishing trip. On average, each platform consumes 6-10 litres of fuel for electricity, while the ferry spends 20-30 litres of fuel on shuttling.

4. Value chain and sharing system

LF fishing involves multiple ownership, as the ferry and each platform belong to different owners. The actual fishing business is conducted on the platform, whilst the ferry provides the transportation**.** After the fishers who operate the platforms sell the catch through the fish seller, the ferry receives a share of the revenue for providing a service. The revenue is also shared with the seller, as an intermediary. Figures 3.31 and 3.32 show the value chain and sharing system in the LF fishing.

Table 3.7 Fishing attributes of the LF vessel

Inputs			**Outputs**
Capital	**Maintenance**	**Supplies**	
Ferry:	Ferry:	Ferry:	Catch
Fishing vessel	Fishing vessel	Diesel fuel	Revenue
Engine	Engine		
Platform:	Platform:	Platform:	
Fishing gear	Fishing gear	Petrol	
Generator	Generator	Lubricant	
Fish containers			
Fuel containers			
Lamps			

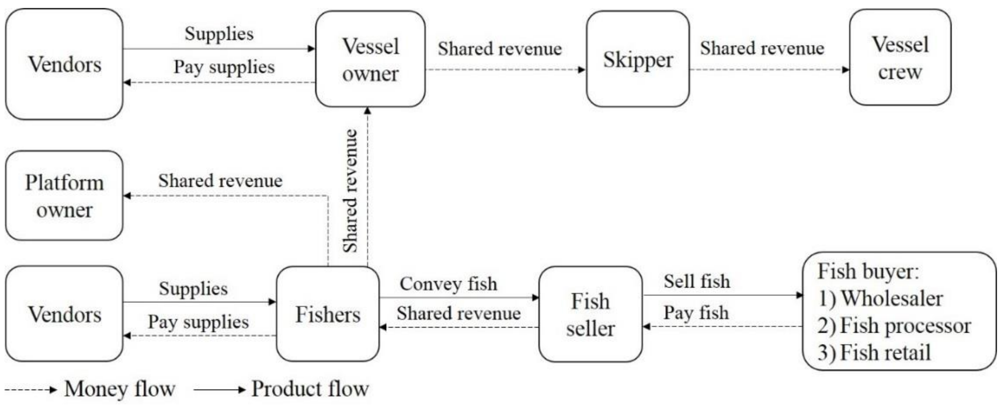


Figure 3.31 Value chain in the LF vessel

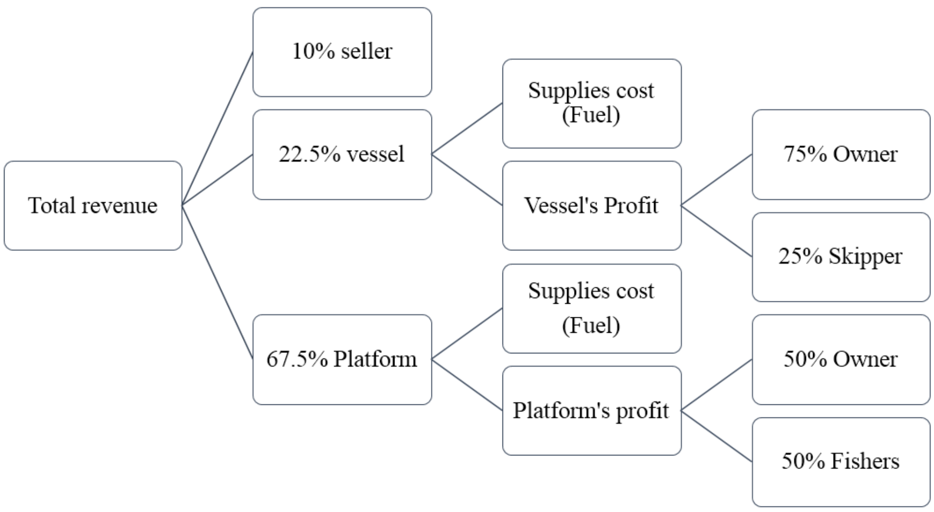


Figure 3.32 Sharing system in the LF vessel

3.6 Summary

Worldwide, Asia leads in fish production, the size of the fishing fleet and the number of fishers. However, its productivity per fishing vessel and fishers were far behind the fishing practices in Oceania and Europe. Furthermore, as the second largest fish producer in Asia, fishing operations in Indonesia are also characterised by the domination of SSFVs, labour intensive, and low productivity. Palabuhanratu is one of the fishing business centres which represents a typical Indonesian fishery.

Regarding the purpose of the study, four types of SSFV in Palabuhanratu was investigated, specifically, PD, TN, HL, and LF vessels. Those vessels represent different types of operation. Based on the operating method, there are active fishing (PD and TN vessels) and passive fishing (HL and LF vessels), and based on the fish target, there are pelagic fishing (PD and LF vessels) and demersal fishing (TN and HL vessels).

In order to understand to the fishing practice in four studied vessels, the first fieldwork was conducted by a survey. Data was collected through three different ways: using fishing port's statistical reports, observing on-board activities and recording fishing productivity, and conducting interviews with 152 respondents. As a result, the general description, operational profile, fishing attributes, value chain actors, and the sharing system are explained in this chapter. In the following chapter, information gathered during the survey is used to develop the fishing operation model.

Chapter 4. Development of a fishing vessel operation model

4.1 Introduction

In Chapter 3, the existing practices, which are described on the basis of the survey, outline the operational profile of the SSFV. In this chapter, the information will be used to develop the fishing operation models consisting of production and fuel consumption models. Both models were specifically constructed for each studied vessel. The following paragraphs describe the development of the models and the modeling outcomes.

4.2 Profit model

As a business activity, the performance of fishing vessel operations is presented in terms of profit, which is a function of costs and revenue (Dahle, 1981).

$$Profit = (catch \times fish\,price) - (fuel\,consumption \times fuel\,price) - other\,costs$$

Equation 4-1

The purpose of the modelling is to depict the fishing productivity of each vessel and profit distribution amongst the stakeholders within one year period. Therefore, information related to catch/trip, fuel and other supplies requirement/trip, the number of fishers/vessel, the number of trips/month, prices and the sharing system are all required. As mentioned in Section 2.7, this model was constructed using the simplified version, hence the value for those variables were defined based on the interviews with the fishers and on statistics obtained from the port. Due to the number of variables, the model was developed using a spreadsheet.

Since catch quantity is highly unpredictable and fluctuates seasonally, the pattern of fishing activities throughout the year were considered, and the model is presented on a monthly basis. The following paragraphs explain the development of the profit model.

4.2.1 Methodology

The profit model was developed in four steps: developing the input variables, defining the fishing pattern, defining the value for input variables, and calculating the profit, as described below

1. Developing the input variables

   Developing the input variables is an essential part of the modelling as it values each variable to calculate profit. In order to produce a representative result, it should be developed as accurately as possible. There are 14 input variables whose values were predefined in this modelling, as presented below.

   a. Fishing trips/month (day)
   b. Successful trip/month (%)
   c. Fuel/trip (litre)
   d. Fuel price/litre (£)
   e. Lubricant/trip (litre)
   f. Lubricant price/litre (£)
   g. Ice/trip (kg)
   h. Ice price/kg (£)
   i. Bait/trip (kg)
   j. Bait price/kg (£)
   k. Catch/trip (kg)
   l. Fish price/kg (£)
   m. Number of fishers/vessel (person)
   n. Number of platforms/vessel (unit)

   It should be noted that not every fishing trip makes a profit. In order to improve the accuracy, potential losses have to be accounted. In fact, the statistics only recorded fishing trips that landed catches, which left unsuccessful trips unrecorded. Therefore, in this study, the percentage of successful trips was included in the calculation.

   As mentioned in Section 3.4.5, fishing operations experience peak, moderate and low seasons. Statistics published by PPN Palabuhanratu (2015) suggests that the fishing trips/month, successful trip/month, fuel/trip, lubricant/trip, catch/trip and fish price/kg fluctuate depending on the season, whilst the remaining variables are constant.

2. Defining the fishing pattern of the changing variables

   The pattern was estimated based on the time series data from 2009-2015. Analysis was applied for four variables including fishing trips/month, fuel/trip, catch/trip and fish price/kg, whilst the pattern of successful trips/month and lubricant/trip is following the number of fishing trips and fuel consumption respectively. The patterns were predicted based on a seasonal index, an index which shows the seasonality of fishing operations throughout the year. The index was calculated by using the centred moving average (CMA) method, a statistical method which extracts the seasonal pattern from time series data by getting a moving average that is centred on an existing midpoint (Newbold *et al.*, 2010).

The calculation was carried out in two-steps, as depicted in Figure 4.1. Step 1 calculates the average of the monthly data (x_i and y_i), which is used to obtain the CMA ratio (r_i). Subsequently, in Step 2, the average of the ratio in the same months (μ_i) is calculated in order to achieve a seasonal index (S_i).

When standard interpretation is applied, the terms on and off seasons are used to refer to the months with S_i which are greater or less than 100 (Newbold *et al.*, 2010). However, considering three fishing seasons, S_i was divided into three ranges based on the maximal and minimal values of the index, and the modified interpretation is described below.

Low season	= $S_i \leq$ delimiter 1
Moderate season	= delimiter 1 < S_i < delimiter 2
Peak season	= $S_i \geq$ delimiter 2

3. Defining the input

CMA method was only used to identify the fishing pattern. The value for both fluctuating and constant variables were estimated based on the result of one-month observation, which can be seen in Appendix F, supported by the interview result. These estimation was subsequently validated by means of the fisher's judgment. Figure 4.2 shows the procedure to develop the value for each variable.

4. Developing the model and calculating the outcomes

After the fishing pattern and the input variables for each season were defined, a spreadsheet was developed to calculate the monthly profit for each fishing operation using Equation 4.1. Furthermore, the applied sharing system described in Section 3.5 were used to calculate profit received by each stakeholder. The model is divided into three parts, specifically data input, profit calculation and the result, as detailed in Appendix G. The calculation was performed in Indonesian Rupiah (Rp), which was converted into Pound Sterling (£) using the fixed currency rate of £1 = Rp16,555. In order to deal with uncertainty, three different calculations were developed representing common, optimistic and pessimistic situations.

Step 1

Year	Month	Fishing trip (q)	Moving average $x_i = \frac{\sum_{i=1}^{n} q_i}{n}$	CMA $y_i = \frac{\sum_{i=1}^{n} x_i}{n}$	Ratio to CMA $r_i = \frac{q_i}{y_i} \times 100\%$
2009	January	q_1			
	February	q_2			
	March	q_3			
	April	q_4			
	May	q_5			
	June	q_6			
	July	q_7	x_7	y_7	r_7
	August	q_8	x_8	y_8	r_8
	September	q_9	x_9	y_9	r_9
	October	q_{10}	x_{10}	y_{10}	r_{10}
	November	q_{11}	x_{11}	y_{11}	r_{11}
	December	q_{12}	x_{12}	y_{12}	r_{12}
2010	January	…	…	…	…
	…	…	…	…	…
	December	…	…	…	…
…	…	…	…	…	…
2015	January	q_{73}	…	…	…
	…	…	x_{79}	y_{78}	r_{78}
	December	q_{84}			

Step 2

Month	2009/ 2010	2010/ 2011	2011/ 2012	2012/ 2013	2013/ 2014	2014/ 2015	Average $\mu_i = \frac{\sum_{i=1}^{n} r_i}{n}$	Seasonal index $Si_i = \frac{\mu_i}{\Sigma\mu} \times k$
July	r_7	r_{19}	…	…	…	r_{67}	μ_1	Si_1
August	r_8	…	…	…	…	…	…	…
September	r_9	…	…	…	…	…	…	…
October	…	…	…	…	…	…	…	…
November	…	…	…	…	…	…	…	…
December	…	…	…	…	…	…	…	…
January	…	…	…	…	…	…	…	…
February	…	…	…	…	…	…	…	…
March	…	…	…	…	…	…	…	…
April	…	…	…	…	…	…	…	…
May	…	…	…	…	…	…	…	…
June	r_{18}	…	…	…	…	r_{78}	μ_{12}	Si_{12}
							$\Sigma\,\mu$	

Where
k = correction factor

By definition, average for each months (**μ**) should be 100, therefore the value of 1200 is used as the correction factor.

Figure 4.1 Centred moving average method

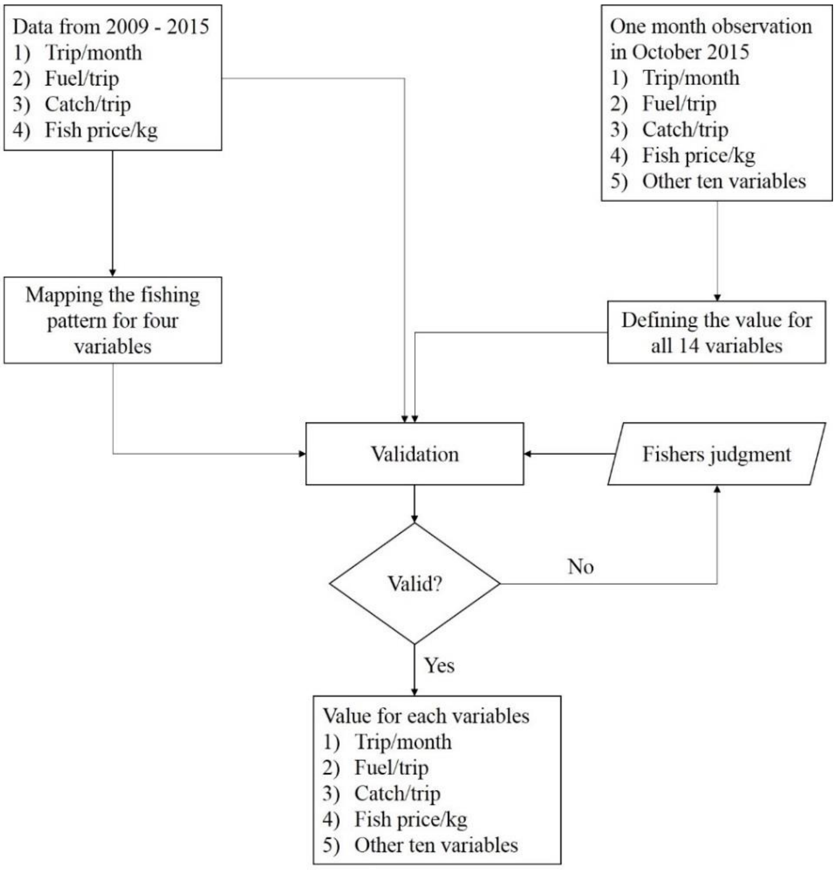


Figure 4.2 Flow chart to develop the value of input variables

4.2.2 Fishing pattern

From the perspective of the vessel, the major variable in relation to fishing operations is the number of the trips, as it indicates the fishing effort. Figure 4.3 presents the seasonal index of the fishing trip for the four studied vessels. According to the type of fish target, pelagic fishing conducted by PD and LF vessels peaks between August and October, whilst demersal fishing conducted by HL and TN vessels peaks twice roughly between October-November and February-March.

Regarding the weather conditions described in Section 3.4.5, it can be noted that most of fishing operations are conducted during the west monsoon period (October-March). However, when the weather becomes rough between December-January, the vessels reduce their fishing trips for safety reasons. A further reduction occurs from April, when the east monsoon blows, until July, when the weather deteriorates again. This happens to all the studied vessels, except for the LF vessel, which displays increasing fishing activities from April to August.

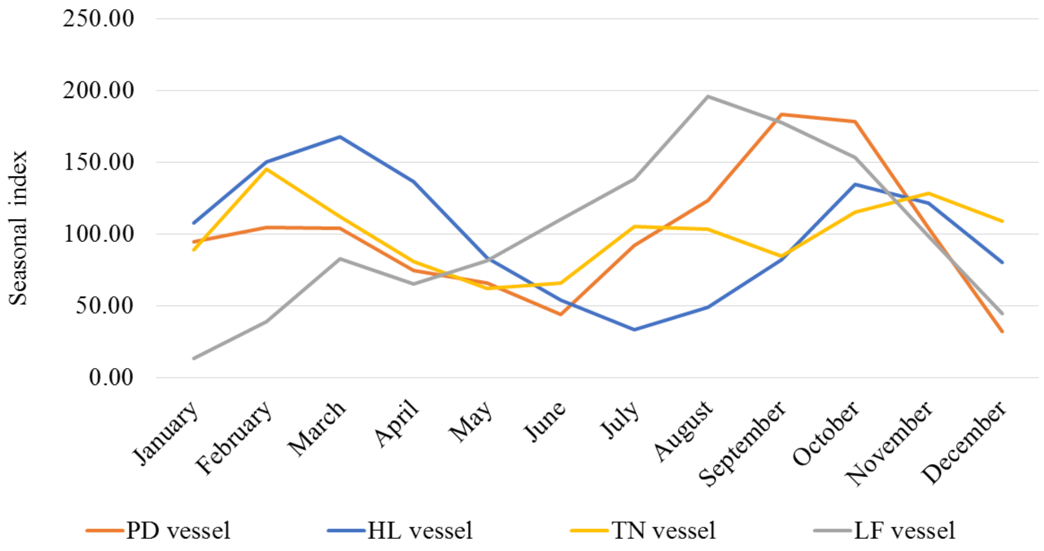


Figure 4.3 Seasonal indices of the studied vessels (using fishing trip variable)

Apart from the weather conditions, fishing seasons generally follow the fish abundance. A study conducted by Wiyono (2001) and Ilhamdi *et al.* (2016), reveals that the abundance of small pelagic fish such as ponyfish, little tuna and sardines in Palabuhanratu Bay and other southern coastal areas of Java island peaked between June and November. In contrast, hairtail fish, lobster and shrimp, which are caught by HL and TN vessels, are typically plentiful from October-April (Boesono *et al.*, 2011; Harjanti *et al.*, 2012), and furthermore, according to Jayanto *et al.* (2013), shrimp might also peak between July-September. The fish seasons do not occur in the same months every year and the period might change because of various environmental factors, such as climate change and ecosystem dynamics (Brönmark *et al.*, 2008; Brander, 2010; Bell *et al.*, 2013). However, it will be around the aforementioned ranges.

Using the seasonal index, the fishing patterns throughout the year have been predicted. Furthermore, fishers were asked to identify the fishing seasons according to their experiences. The result was used to validate the pattern obtained from the calculation, as shown in Table 4.1.

Table 4.1 Comparison of the fishing trip pattern between the seasonal index calculation and fishers' knowledge

Fishing trip vs fishers' version													
Fishing vessel	**Fishing season**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
PD vessel	Calculation	Mod	Mod	Mod	Low	Low	Low	Mod	Mod	Peak	Peak	Mod	Low
	Fishers' version	Low	Low	Low	Mod	Mod	Mod	Peak	Peak	Peak	Mod	Mod	Low
TN vessel	Calculation	Mod	Peak	Peak	Low	Low	Low	Mod	Mod	Mod	Peak	Peak	Peak
	Fishers' version	Peak	Peak	Mod	Mod	Low	Low	Low	Mod	Mod	Mod	Peak	Peak
HL vessel	Calculation	Mod	Peak	Peak	Peak	Mod	Low	Low	Low	Mod	Peak	Mod	Mod
	Fishers' version	Low	Low	Mod	Peak	Peak	Mod	Low	Mod	Mod	Peak	Peak	Low
LF vessel	Calculation	Low	Low	Mod	Low	Mod	Mod	Peak	Peak	Peak	Peak	Mod	Low
	Fishers' version	Low	Low	Low	Mod	Mod	Mod	Mod	Peak	Peak	Peak	Mod	Low

The comparison confirms that in general, both versions reveal a matching pattern, and most importantly, the period and length of each season resulting from the calculation correspond to the fishers' knowledge. However, it should be noted that some dissimilarities appear due to different interpretations and the fact that the fishing seasons are changing over time. For example, respondents from PD vessels claimed that July-September is the typical fishing peak season, as described in the following statements:

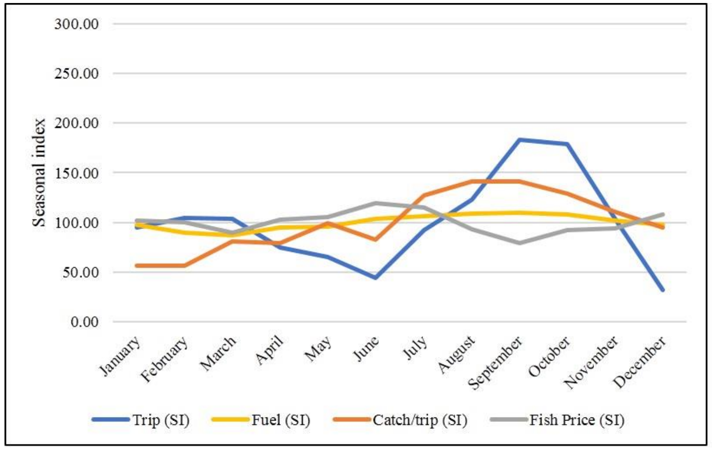
> *"The fish are typically abundant starting from June onward, but now even though it is already September, it is just average" (Respondent F.1.2.1)*

> *"The peak season is typically from July to September but this year we did more fishing in September and October, even though we are about facing the west monsoon" (Respondent O.1.0.1)*

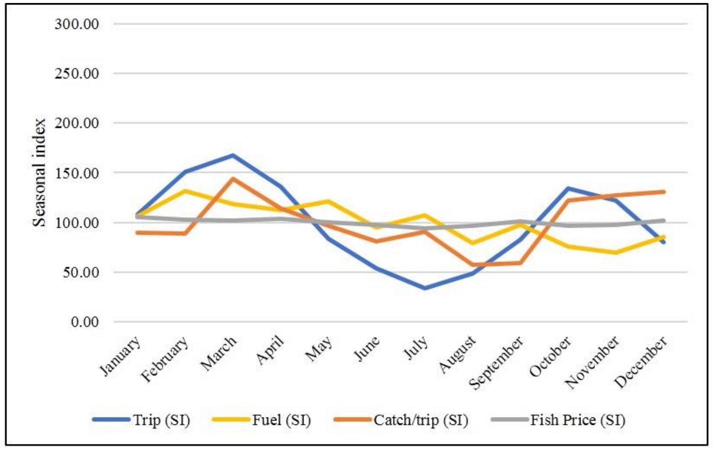
In fact, the calculation result shows that it occurs between September and October. Therefore, despite of some dissimilarities between both versions, the fishing pattern resulted from the calculation was subsequently used for further modelling.

Besides the fishing trip, other variables, such as catch/trip, fish price/trip and fuel/trip also change seasonally. By using the CMA method, the seasonal index for other variables is presented in Figure 4.4. Subsequently, it was interpreted into three seasons. The result is presented in Table 4.2.

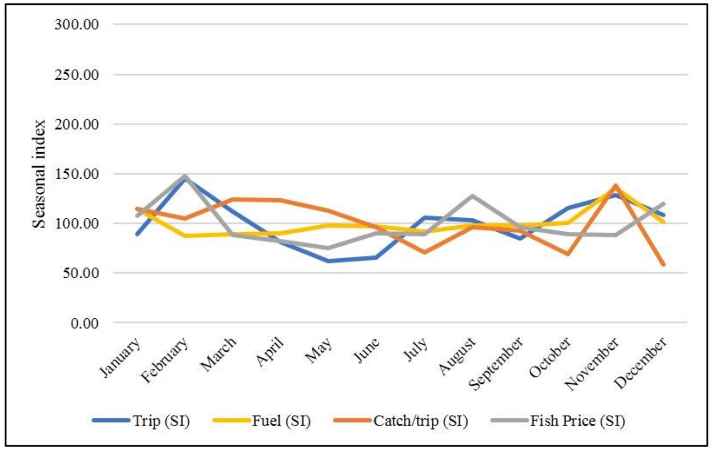
Both illustration reveal that each variable has a different trend, which is not necessarily in line with other variables. For example, in the PD vessel, when the catches and the number of trips are low in June, fuel use peaks because the vessels spend more time at sea. Conversely, the LF vessel carries roughly the same amount of fuel throughout the year due to less varying route. Regarding the market situation, fish prices for PD and TN



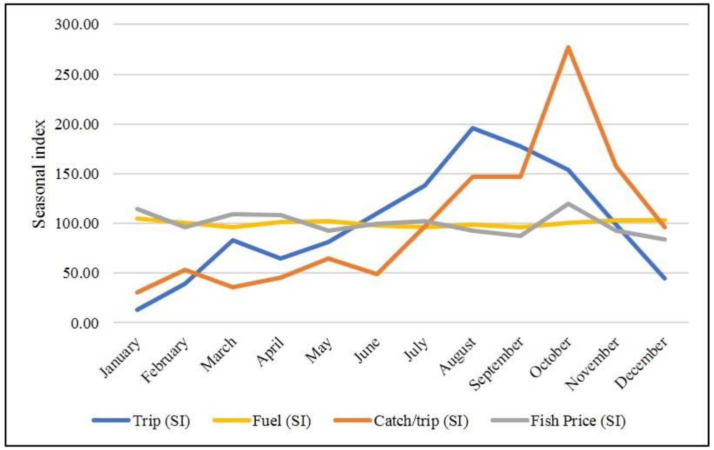
PD vessel



LF vessel



TN vessel



HL vessel

Figure 4.4 Seasonal index of the studied vessels

Table 4.2 Seasonal fishing patterns of the studied vessels

Fishing vessel	Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PD vessel	Trip/month	Mod	Mod	Mod	Low	Low	Low	Mod	Mod	Peak	Peak	Mod	Low
	Fuel/trip	Mod	Low	Low	Mod	Mod	Peak	Peak	Peak	Peak	Peak	Peak	Mod
	Catch/trip	Low	Low	Low	Low	Mod	Low	Peak	Peak	Peak	Peak	Mod	Mod
	Fish price/kg	Mod	Mod	Low	Mod	Mod	Peak	Peak	Mod	Low	Low	Mod	Peak
TN vessel	Trip/month	Mod	Peak	Peak	Low	Low	Low	Mod	Mod	Mod	Peak	Peak	Peak
	Fuel/trip	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low	Peak	Low
	Catch/trip	Peak	Mod	Peak	Peak	Peak	Mod	Low	Mod	Mod	Low	Peak	Low
	Fish price/kg	Mod	Peak	Low	Low	Low	Low	Low	Peak	Low	Low	Low	Mod
HL vessel	Trip/month	Mod	Peak	Peak	Peak	Mod	Low	Low	Low	Mod	Peak	Mod	Mod
	Fuel/trip	Mod	Peak	Peak	Peak	Peak	Mod	Mod	Low	Mod	Low	Low	Low
	Catch/trip	Mod	Mod	Peak	Mod	Mod	Low	Mod	Low	Low	Peak	Peak	Peak
	Fish price/kg	Peak	Peak	Peak	Peak	Mod	Low	Low	Low	Mod	Low	Low	Peak
LF vessel	Trip/month	Low	Low	Mod	Low	Mod	Mod	Peak	Peak	Peak	Peak	Mod	Low
	Fuel/trip	Peak	Mod	Low	Mod	Peak	Low	Low	Low	Low	Mod	Peak	Peak
	Catch/trip	Low	Low	Low	Low	Low	Low	Mod	Peak	Peak	Peak	Peak	Mod
	Fish price/kg	Peak	Low	Peak	Mod	Low	Low	Low	Low	Low	Mod	Low	Low

vessels are fluctuating, whilst for HL and LF vessels the price ordinarily remains constant regardless of the seasons. Most importantly, the weight of catch/trip does not necessarily peak when the trip number is at its highest point. Ignoring the fluctuation of each variable might lead to inaccuracy, therefore, following the pattern obtained from the seasonal index is the most accurate way to model the existing practice.

4.2.3 Input variables for annual production data

Table 4.3 presents the seasonally-based inputs, which were used to calculate the production data of each vessel and subsequently the profit. It can be seen that some variables fluctuate following the fishing season, whilst the some others remain constant. Furthermore, the table shows that common, optimistic and pessimistic scenarios were applied by changing the percentage of successful trips/month.

4.2.4 Modelling result

Figure 4.5 shows the modelling result presented on a monthly basis. It can be seen that the profit pattern of each fishing vessel generally follows the fishing pattern described in Figure 4.4. Income for pelagic fishing, performed by PD and LF vessels, peaks during the second half, whilst for demersal fishing, conducted by TN and HL vessels, peak at the beginning and the end of the year. The income will significantly decreases during the low season, even worse, it can be a loss for the owner.

Table 4.3 Input variables for annual production data

Variable	PD vessel			TN vessel			HL vessel			LF vessel					
										Ferry			Single platform		
	Peak	Moderate	Low	Peak	Moderate	Low	Peak	Moderate	Low	Peak	Moderate	Low	Peak	Moderate	Low
Fishing days (day/month)	25	20	12	25	20	12	25	20	12	24	18	12	24	18	12
Successful trip (%)	90%	80%	70%	90%	80%	70%	90%	80%	70%	90%	80%	70%	90%	80%	70%
Optimistic	100%	90%	80%	100%	90%	80%	100%	90%	80%	100%	90%	80%	100%	90%	80%
Pesimistic	80%	70%	60%	80%	70%	60%	80%	70%	60%	80%	70%	60%	80%	70%	60%
Fuel/trip (litre)	120	90	60	30	25	15	10	8	5	30	25	20	15	10	8
Fuel price (£/litre)	0.40	0.40	0.40	0.31	0.31	0.31	0.40	0.40	0.40	0.31	0.31	0.31	0.40	0.40	0.40
Lubricant/trip (litre)	4	3	2	-	-	-	0.33	0.27	0.17	-	-	-	0.50	0.33	0.27
Lubricant price (£/litre)	1.81	1.81	1.81	-	-	-	1.81	1.81	1.81	-	-	-	1.81	1.81	1.81
Ice/trip (kg)	63	63	63	25	25	25	25	25	25	-	-	-	-	-	-
Ice price (£/kg)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	-	-	-	-	-	-
Bait/trip (kg)	-	-	-	-	-	-	3	3	3	-	-	-	-	-	-
Bait price (£/kg)	-	-	-	-	-	-	0.30	0.30	0.30	-	-	-	-	-	-
Catch/trip (kg)	500	300	150	25	15	5	30	20	5	-	-	-	100	40	20
Fish price (£/kg)	0.79	0.60	0.39	4.53	3.32	2.42	1.57	1.51	1.45	-	-	-	0.51	0.39	0.33
Number of fishers (person)	10	10	10	2	2	2	2	2	2	-	-	-	1	1	1
Number of platforms (unit)	-	-	-	-	-	-	-	-	-	10	10	10	-	-	-

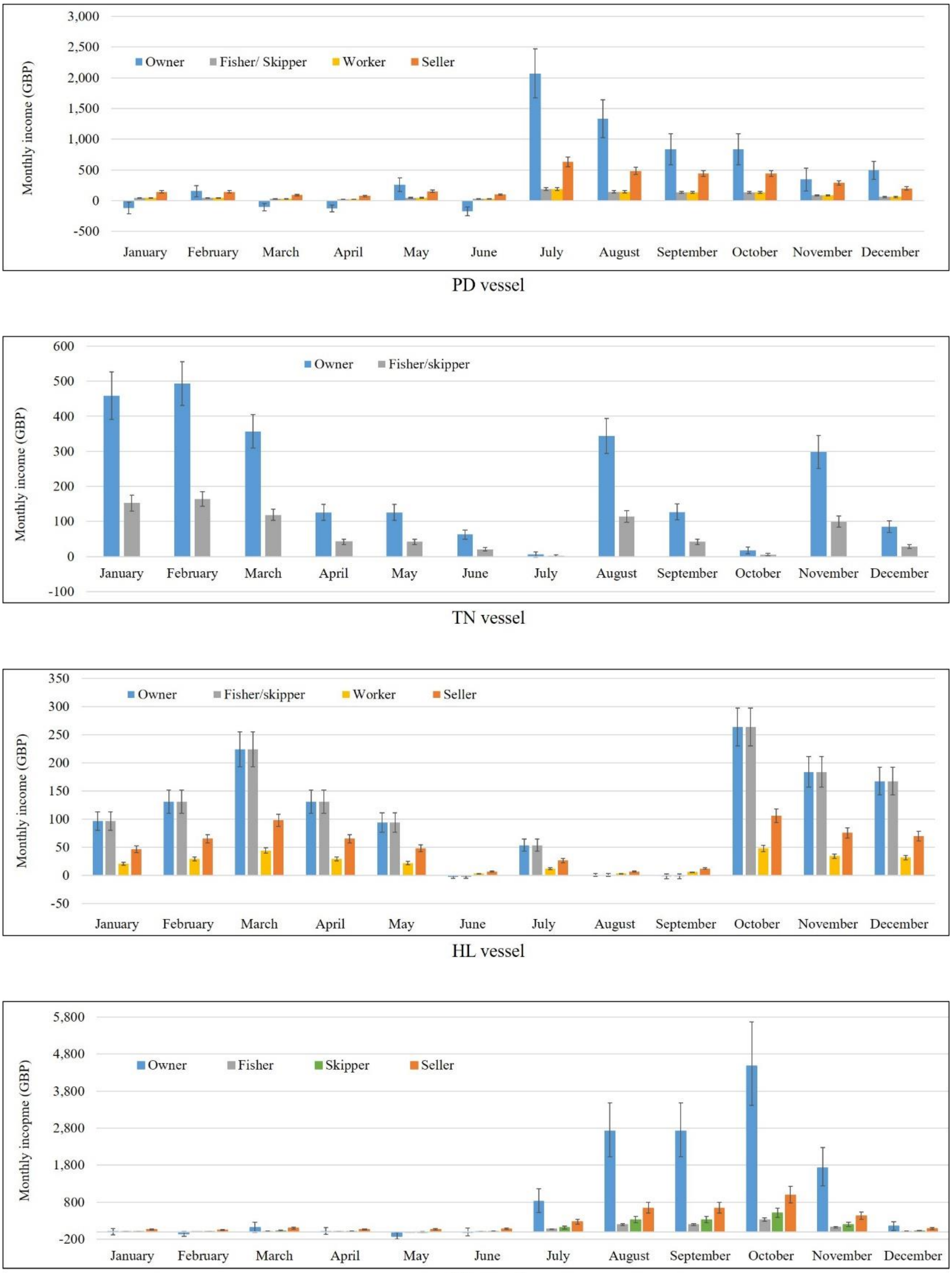


Figure 4.5 Monthly income (in GBP) for each stakeholder on the studied vessels

Figure 4.5 also shows the profit distribution amongst the stakeholders involved along the fish production system. Generally, it is revealed that there is an income inequality, as a result from the fish trade along the value chain. Furthermore, the fisher is likely to earn the lowest income compared to other stakeholders. This result shows a similar finding to studies conducted by Kaplinsky (2000) and Wamukota *et al.* (2014).

The Indonesian government has regulated that the minimum share for fishers in the motorised vessels is 40% of the net revenue (*Law No 16 of 1964 (on) Fisheries Sharing System*). If the net revenue is the total money shared between the owner and the fishers, Figure 4.6 shows that the fishers' shares (personnel cost) in all vessel comply with the regulation. The share is 43% in PD and LF vessels, 50% in TN vessel and 69% in HL vessel. However, according to the regulation, the net revenue is the revenue after the deduction of costs for food, port fees and selling fees from the gross revenue. Consequently, costs associated with supplies should be the owner's responsibility. As described in the sharing system for each vessel (Figure 3.17, 3.22, 3.27 and 3.32), it is revealed only the PD vessel complies with the regulation, as the profit is shared without supplies cost deduction.

Furthermore, Figure 4.6 illustrates the annual profit of the selected studies presented based on the total revenue and operational costs consisting of supplies, selling, and personnel costs. The error bars shown in the figure indicate the optimistic and pessimistic scenarios. The figure shows that the supplies and personnel costs take the largest allocation, with personnel cost is the highest ranging from 27% to 47%. A study conducted by Hewamanage (2010) reveals that the allocation for fishers payment gradually decreases as the size of the vessel increases. This agrees with the result of this study, which show that the percentage of the personnel cost in HL vessel (3 GT) is the highest compare to other vessels (5 GT).

Values for input variables presented in Table 1.3 were based on the estimation, as described in Figure 4.2. In the next chapter, the same inputs were used to assess environmental and economic impacts. In order to ensure the reliability of this model in representing the existing operations, further validation is carried out by comparing the production data calculated from this model to the statistics reports, as shown in Table 4.4.

Table 4.4 Comparison between assumed production data and the statistics

Fishing vessels	**Fuel/trip (litres)**		**Catch/trip (kg)**		**Value/trip (£)**	
	This study	**Statistic**	**This study**	**Statistic**	**This study**	**Statistic**
PD vessel	101	100	266	388	147	165
TN vessel	17	22	13	12	27	26
HL vessel	10	10	18	23	27	26
LF vessel	104	89	486	512	170	194

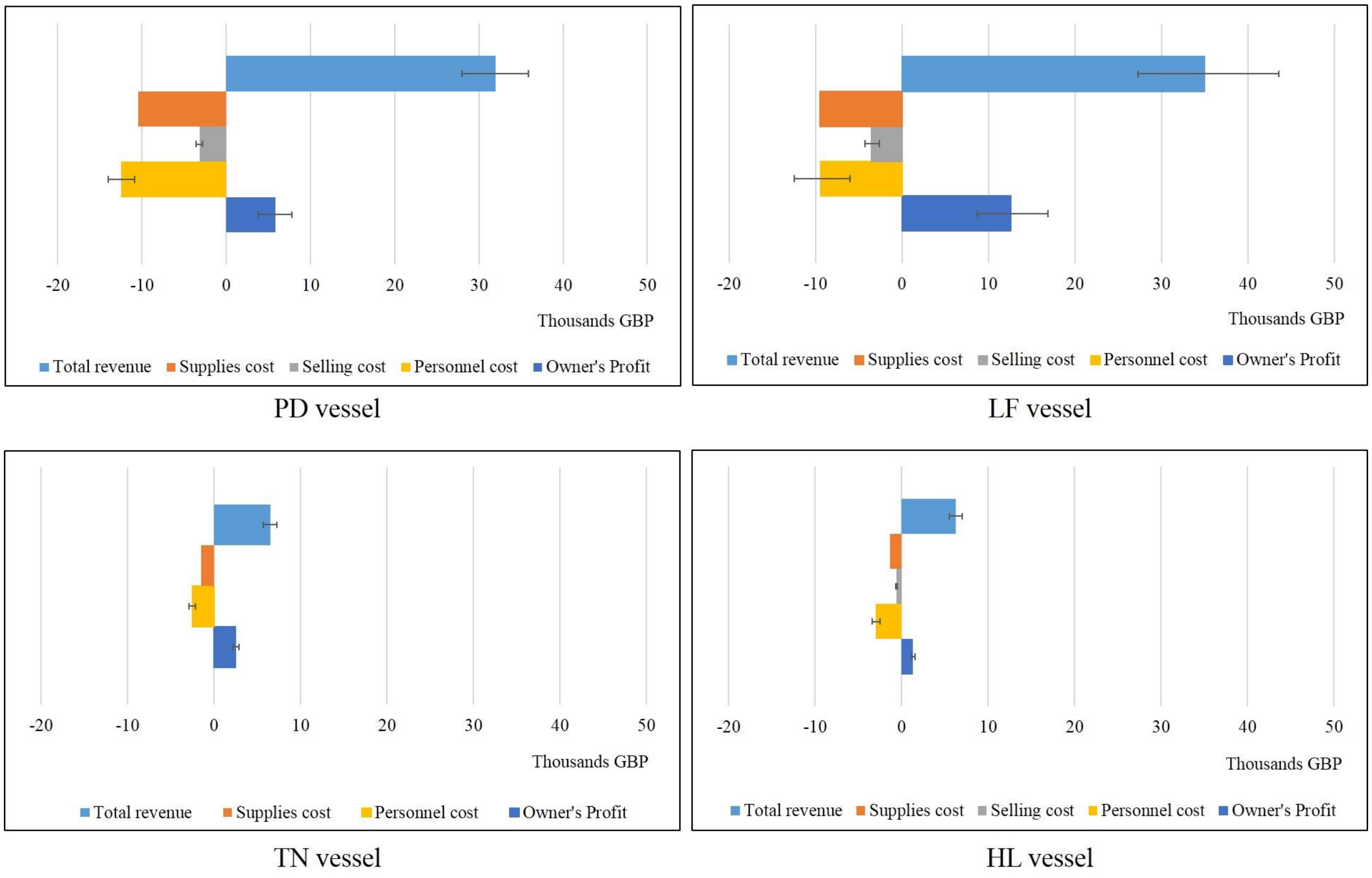


Figure 4.6 Annual profit and cost allocation (in thousands GBP) of the studied vessels

The table shows that there are some differences between inputs variables used in this study and statistics, which are explained below:

1. Regarding fuel/trip, the significant difference is found in the TN and LF vessels. According to the statistics, the amount of fuel supplied in the TN vessel is between 20 – 30 litres. In fact, the fishers sometimes bring only 15 litres. Fuel used in the LF platform might vary from 6 to 10 litres. Whilst the statistics recorded 7 litres, this study used 8 litres following the observation result.

2. The catch/trip value defined for each vessel are mostly smaller than the statistics. It is because the statistics aggregated the reported data from 2009 to 2015 and only included successful trips. In contrast, unsuccessful trips are considered in this study. Furthermore, unlike other vessels, data obtained from the TN fishers was slightly higher than data from the statistics. Given that the unsuccessful trips have been considered, this confirms that catch quantity reported in the statistics is lower that the reality.

3. The dissimilarity in the catch/trip affects the value/trip. Besides, it is also influenced by the fish price, which for the purpose of this study, employed 2015 prices as references.

Given that all significant differences are explainable and the values were developed by considering the inputs from the fishers, it is argued that the model is capable of representing the existing practices.

4.3 Fuel consumption model

A fishing operation is conducted at a range of speed depending on the type of activities undertaken during the fish catching process, which eventually affect fuel consumption. Since fuel has been allocated for each trip, the skipper will use most of it. If there is remaining fuel, it will be kept as a spare for the next trip. The fishers are aware of the importance of managing speed to save the fuel, because it affects the operational cost and their share. However, how much this affects fuel saving remains unclear.

In order to analyse the impact of speed management on total fuel consumption, another model was developed to predict fuel consumption at different operational loads based on the data from one-day observation. The modeling result is not used in the profit model, but it is used in the formulation of the possible measures to manage speed.

4.3.1 Methodology

Ideally, fuel consumption rates are collected using a fuel flow meter. However, due to technical limitations, fuel consumption data was obtained based on the amount of fuel before and after the fishing trip. Therefore, fuel consumption rates were estimated using the following approach.

1. Mathematically, fuel consumption rate (litres/hr) is the function of speed (v_s) and a constant coefficient (k) that each engine has. This means fuel consumption for the entire trip (Q_{fsum}) can be calculated if running time (t_s) and fuel consumption at idle speed (Q_{fo}) were identified, as seen in Equation 4.2.

2. Data v_s, t_s, and Q_{fsum} were recorded several times (from i to n) during the fishing operation. Q_{fo} was assumed to be 0.5 litres/hr, based on the average of fuel consumption at idle speed on the traditional boats which was investigated by (Tumigolung *et al.*, 2017) . The constant k was obtained using *what-if analysis*, an analysis which explores various result by changing the value in cells to see how those changes affect the outcome.

$$Q_{fsum} = \sum_{i=1}^{n} \left(Q_{fo} + \ k v_{si}^3\right) . \, t_{si}$$

Equation 4-2

3. As the HP and v_s were known, subsequently specific fuel consumption (SFC) was estimated by assuming that fuel density (ρ_f) is constant.

4.3.2 Modelling Result

Table 4.5 shows the example of one-day observation result from the PD vessel, whilst result from other vessels are provided in Appendix H. According to the observation results, time allocation for each activity including the average speed and total fuel consumption were plotted as illustrated in Figure 4.7. The figure shows that in the PD vessel, most of the fishing time is spent for locating the fish, followed by steaming, which refers to the voyage between the port and the main fishing ground. A large percentage on fish locating and steaming indicates that the vessel actively moves during the operation.

Table 4.5 Result of one-day observation in the PD vessel

Operation phase	Duration (minutes)	Main Engine	Power	Speed (knots)
Start 05.30 am				
Loading	00:15:42	off	off	0.00
Manoeuvring	00:01:40	on	25%	1.51
Steaming	00:10:49	on	75%	6.26
Setting	00:05:13	on	50%	4.64
Hauling	00:17:03	off	off	0.00
Steaming	02:05:00	on	75%	7.18
Setting	00:05:30	on	50%	5.56
Hauling	00:16:22	off	off	0.00
Steaming	00:43:20	on	50%	5.35
neSetting	00:05:21	on	50%	4.97
Hauling	00:16:22	off	off	0.00
Steaming	01:20:27	on	75%	6.05
Setting	00:05:19	on	50%	4.75
Hauling	00:16:10	off	off	0.00
Steaming	01:24:08	on	75%	6.91
Anchoring/Break	00:45:58	off	off	0.00
Steaming	03:54:20	on	75%	7.45
Manoeuvring	00:01:37	on	25%	1.67
Unloading	00:10:03	off	off	0.00
Manoeuvring	00:01:51	on	25%	1.57
Finish 17.53 pm	**12:22:15**			

The TN vessel can undertake active or passive methods. When performing active fishing, the TN vessel is mostly moving either steaming, fish hunting or encircling. In contrast, when a passive operation is conducted, the vessel only performs a return voyage to set and haul the net, as the net is left deployed at the fishing ground. In the LF vessel, the ferry also conducts return voyage between the port and platforms to shuttle the fishers, and it can be seen that the largest fishing time is spent in the LF platforms. Another small vessel movement is found in the HL vessel, as the fishing operation is conducted whilst the vessel is anchored.

Compared to other vessels, steaming time in the PD vessel is the largest percentage, showing that it goes to the farthest fishing ground. Furthermore, the figure shows that the TN vessel allocates significant time on hauling process, this is due to the difficulty to collect the entangled catch from the net one by one. The longest duration is found in the TN vessel with the passive method, which takes up to 27 hours due to the requirement to soak the net for at least 12 hours. Regarding the speed, the highest speed is found during steaming in all vessel, as it is very common for skippers to run the vessels at high speed when heading back to the port.

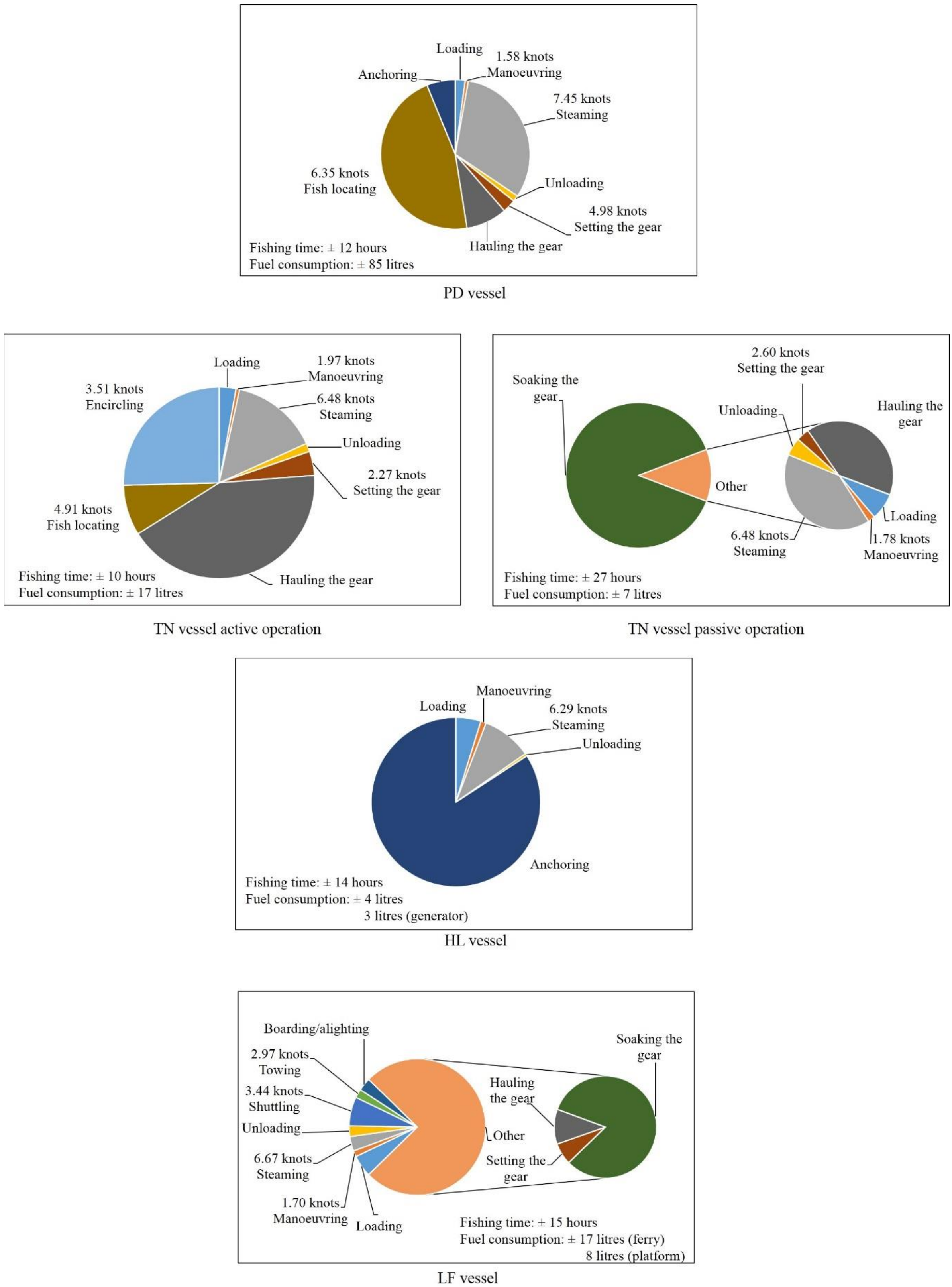


Figure 4.7 Summary of one-day observation based on time allocation

Subsequently, data from on-board observation was used to calculate the constant k. As a result, fuel consumption for each vessel was modelled followed by SFC calculations, as seen in Figure 4.8 and Figure 4.9. The figures confirm that petrol engines consume more fuel than diesel engines.

Furthermore, when compared to the engine specification (Appendix C), there are slight differences to SFC estimated from this model, given the largest discrepancy is 10.5%, which is found in the PD vessel. Therefore, despite no SFC reference for the LF vessel being found, it is argued that this model can be used for further calculation.

Using information presented in Figure 4.7 and 4.8, fuel consumption for each fishing stage was estimated, which is presented in Table 4.6. For active operations, fuel is spent for steaming, fish locating and setting gear or encircling. Whilst for passive operations, fuel is primarily used for steaming. It should be noted that fuel consumption in the HL and LF vessels exclude fuel used for the generator as presented in the table.

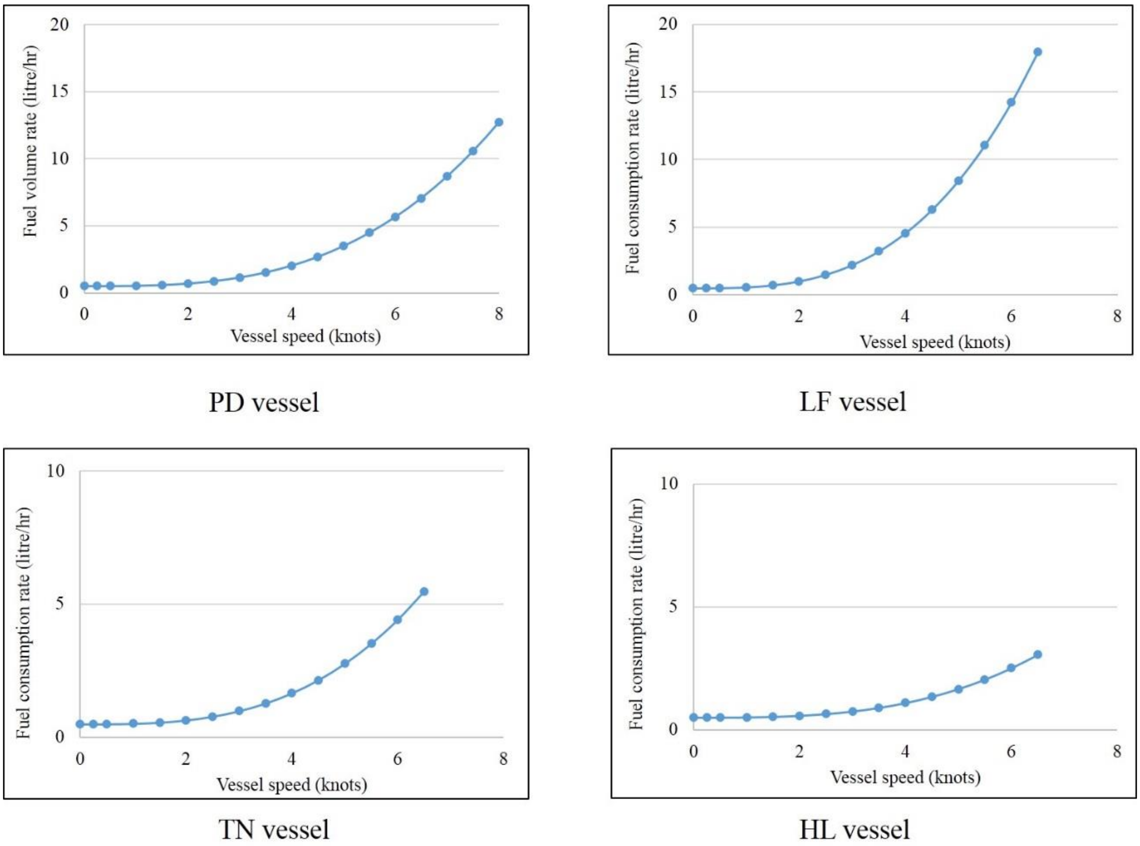


Figure 4.8 Fuel consumption rate (litres/hr) of studied vessels

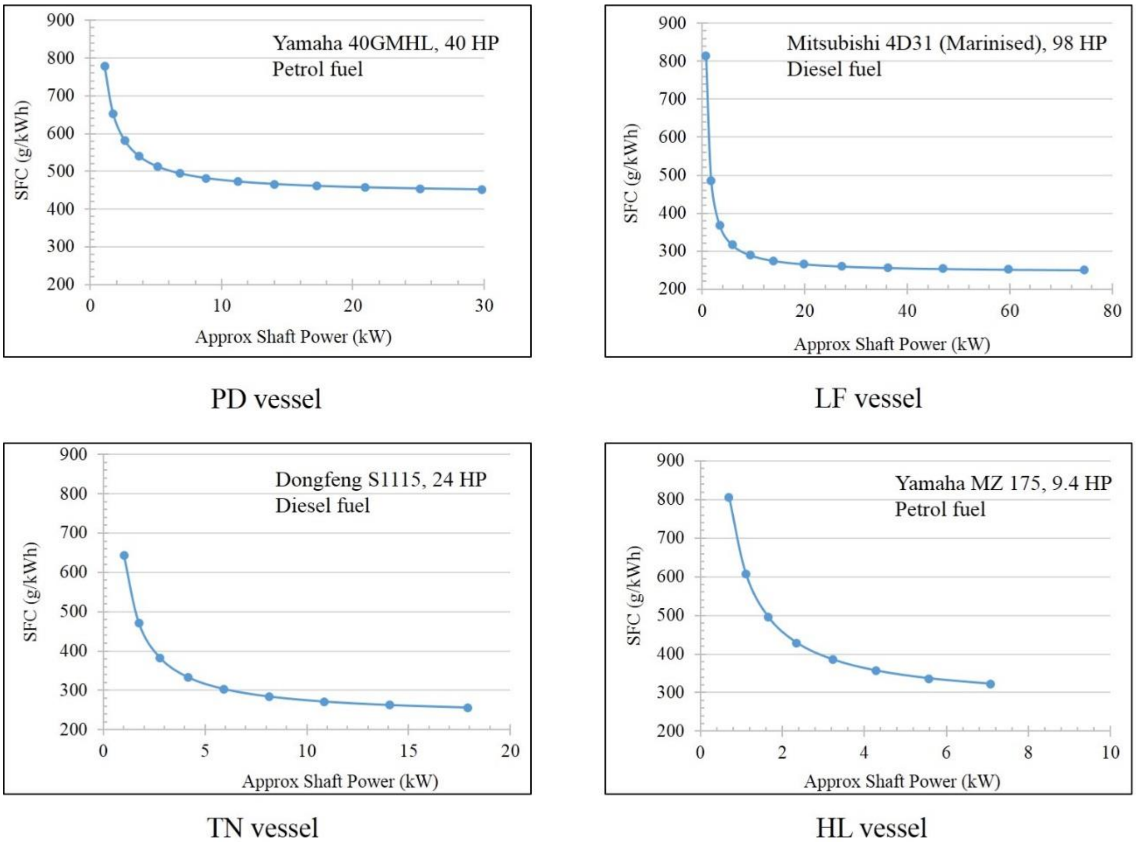


Figure 4.9 Specific fuel consumption (g/kWh) of studied vessels

Table 4.6 Estimation of fuel consumption (litres) for each fishing stage

Fishing stage	PD vessel	TN vessel active	TN vessel passive	HL vessel	LF vessel
Loading	-	-	-	-	-
Manoeuvring	0.05	0.05	-	-	0.18
Steaming	40.56	9.64	6.86	3.50	10.40
Fish locating	43.14	2.72	n/a	n/a	n/a
Setting the gear	1.25	0.35	-		
Soaking the gear	n/a	-	-	3*	80**
Hauling the gear	-	-	-		
Unloading	-	-	-	-	-
Encircling		3.88			n/a
Shuttling	n/a		n/a	n/a	5.39
Towing		n/a			0.72
Boarding/Alighting					0.24
Total fuel (litres)	**85**	**17**	**7**	**4**	**17**

Note: *the vessel is anchored and the fuel is spent for generator
**the vessel returns to the port and the fuel is spent for generator in the 10 platforms

4.4 Summary

In this chapter, the fishing vessel operation has been described using profit and fuel consumption model. The purpose of the first modelling is to estimate the profit and its distribution amongst the stakeholders. It is developed based on the generic profit formulation using predefined input variables, which are constructed through statistical analysis, observation and interviews with the fishers. The model illustrates the fishing profit throughout the year, which is presented on a monthly basis for common, optimistic, and pessimistic scenarios.

The second model portrays time and speed allocation as well as fuel consumption throughout the fishing proses. Regarding time allocation, it is clearly seen that active and passive fishing operations show a significantly different pattern. In relation to speed, the vessels in both operations are typically run at high speed during the steaming. This model enables prediction of the fuel consumption at different fishing stage, and the result shows that steaming consumes a remarkable amount of fuel in all vessels.

In the next chapter, the profit model is used for calculating annual productivity, as the basis information for environment and economic impact assessment. Furthermore, the fuel consumption model is used for analysing possible measures in relation to fuel reduction, which will be further discussed in Chapter 6.

Chapter 5. Result of sustainability assessment of fishing vessels operations

5.1 Introduction

Following the modelling of fishing vessel operation, this chapter describes the sustainability assessment of fishing vessel operations, which is conducted in two steps i.e. calculating the impacts of SSFV operations and aggregating the assessment result in order to produce the performance score for each studied vessel. Numerous aspects will be covered in this chapter including a scoping analysis (Section 5.2), environmental impacts (Section 5.3), economic impacts (Section 5.4), social impacts (Section 5.5) and the sustainability performance (Section 5.6). Data inputs for the assessment is primarily information related to the fishing operations of the selected vessels, which have been described in Sections 3.5 and modelled in Chapter 4.

5.2 Assessment scope

The sustainability assessment is conducted to address the first research question concerning on the sustainability status of the existing SSFV operations. Due to the complexity of the fishing operations and the requirement to involve a range of assessments, scoping analysis is essential. It defines the depth of the assessment, which is aligned with the study purpose (OECD, 2010). At this level, the investigation target, analysis tool and considered stakeholders are specified.

Figure 5.1 summarises the operational profile of each vessel described in Section 3.5, which include activities from preparation of the vessel until the vessel lands the catch and be ready for the next operation. This means the investigation target will include the impacts generated from all the fishing attributes related to the operation of each vessel, as listed in Tables 3.4 – 3.7. However, excluded are impacts produced from the activities before the loading supplies and after the fish selling process.

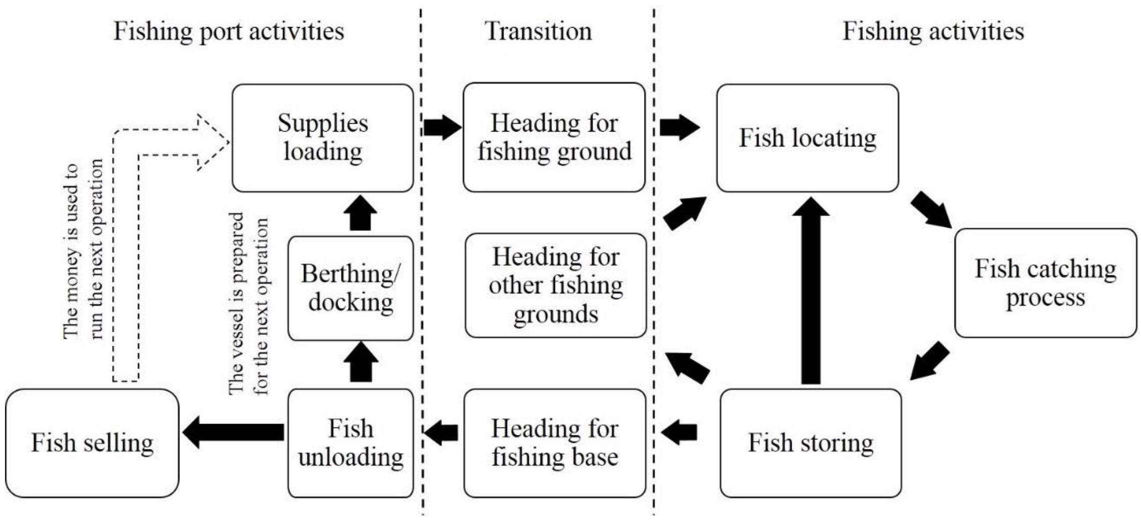


Figure 5.1 Investigation scope for sustainability assessment

Figure 5.2 illustrates the tools of analysis applied in this study. It can be seen that the sustainability assessment of SSFV operations is presented in terms of environmental, economic and social performance, which is evaluated on the basis of impact analysis. The assessment is conducted on four vessels. Hence, the comparison is conducted internally amongst the studied vessels in order to produce the proportional scores. The figure shows that each impact is assessed by way of a life cycle analysis, with additional assessment applied for environmental and economic impacts. When conducting a fishing operation, the vessel's performance in terms of fish quantity and monetary value is not necessarily the same. Therefore, in order to show the performance of the fishing operation in both terms, two functional units (FU) used i.e. per kg fish production and per £ revenue. Further detail about the tool of analysis for each impact is provided in Section 5.3, 5.4 and 5.5.

The stakeholders involved in the impact assessment process consist of workers, value chain actors, the local community and wider society (Table 3.3). The first two groups represent people who are primarily involved in the fishing business such as fishers, owners, and sellers, whilst the remaining stakeholders incorporates the other members of the fishing community and the government. Having specified the investigation area, analysis tools and the relevant stakeholders, the following sections will discuss the calculation method and the result from each analysis.

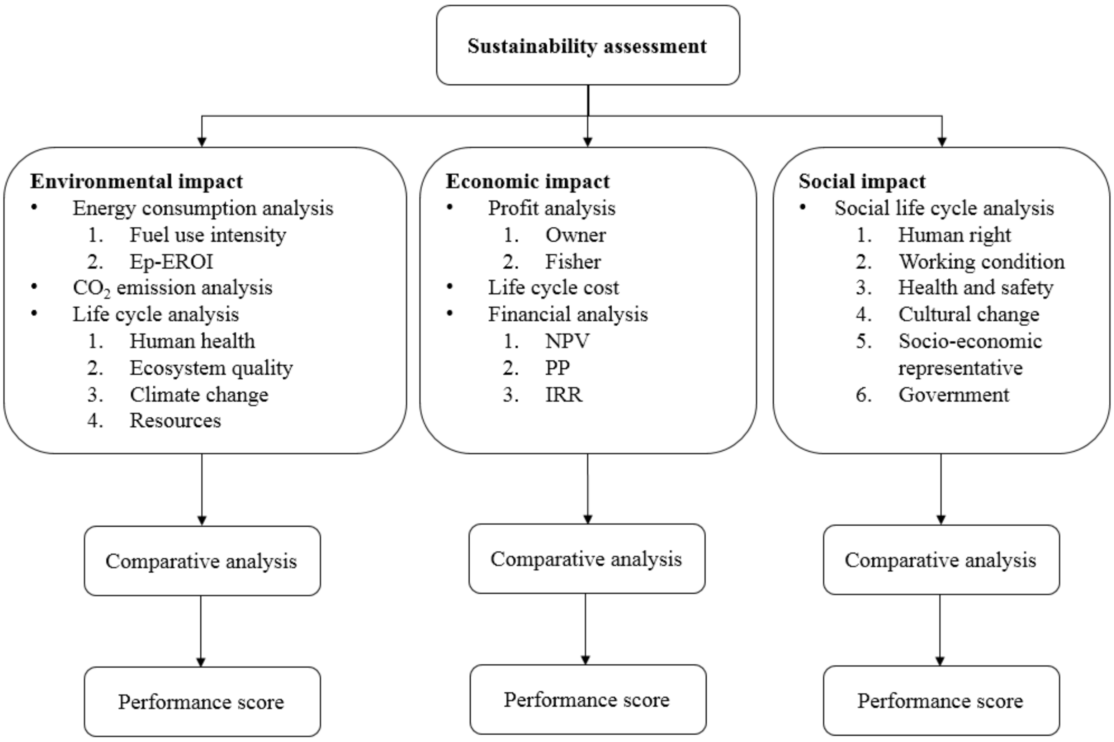


Figure 5.2 Tools of analysis applied in sustainability assessment

5.3 Environmental impacts

5.3.1 Energy consumption analysis

Energy consumption in the selected fishing operations was analysed using FUI and ep-EROI. The first indicator denotes the fuel consumption, whilst the second one represents the percentage of energy derived from edible protein yield per energy unit that is consumed to obtain it. Accordingly, FUI should be kept at the minimum level, in contrast to ep-EROI which should be maximised. Regarding the concept of sustainable development in fisheries, ep-EROI is not strongly linked to the protection of marine resources and environment since it focuses on the yielded protein. The purpose of calculating ep-EROI in this thesis is to provide comprehensive assessment in terms of energy use in fishing activities. The next paragraphs present the method and result of energy consumption analysis in four studied vessels.

5.3.1.1Methodology

Both FUI and ep-EROI are calculated based on annual data. Hence, mathematically, FUI is obtained by way of dividing annual fuel consumption by annual catch or revenue

(Equation 5.1 and 5.2), whilst ep-EROI is the energy ratio between the protein yielded from fish and total fuel consumption throughout one year of operation (Tyedmers, 2004).

$$FUI_{kg} = \frac{\sum_{i=1}^{n} F_i}{\sum_{i=1}^{n} Q_i}, \text{ [litres fuel/kg catch]}$$

Equation 5-1

$$FUI_{£} = \frac{\sum_{i=1}^{n} F_i}{\sum_{i=1}^{n} R_i}, \text{ [litres fuel/£ revenue]}$$

Equation 5-2

$$ep - EROI = \frac{\sum_{i=1}^{n} Q_i \, C.P.c_p}{\sum_{i=1}^{n} F_i \, .\rho.c_f}$$

Equation 5-3

Where:
F_i, = annual fuel consumption (l)
Q_i, = annual fish production (kg)
R_i = annual revenue (£)
C = ratio of edible portion (%)
P = protein content per edible portion (%)
c_p = protein calorific value
c_f = fuel calorific value
ρ = fuel density

The main data inputs incorporating annual fuel consumption, catch and revenue were projected using the fishing operation model, as demonstrated in Section 4.6. For ep-EROI calculation, the percentage of edible portion and its protein content were estimated based on fish nutritional values suggested by FAO, which were published in 1989 with no updated report is found. Furthermore, seeing as different fish have different nutritional values, the protein yield was calculated based on the value of the main catch from each vessel. Tables 5.1 and 5.2 show the references applied for energy consumption analysis and protein yield calculation.

The analysis was calculated using the projected data for a single vessel, which will be used for the subsequent impact assessment. Validation is required to ensure that the modelling represents the existing fishing practice. As a result, the performance of each vessel was assessed by means of a comparison between the projected and statistics data.

Table 5.1 References applied for energy consumption analysis

Parameter	Conversion factor	References
£1	Rp 16,555	(Oanda, 2016)
Protein calorific value (c_p)	17,866 kJ/kg	(FAO, 2003b)
Petrol density (ρ)	0.747 kg/l	(DGOG, 2013a)*
Diesel density (ρ)	0.837 kg/l	(DGOG, 2013b)*
Petrol calorific value (c_f)	44,000 kJ/kg	(Demirel, 2012)
Diesel calorific value (c_f)	43,200 kJ/kg	(Demirel, 2012)

*DGOG: Directorate general of oil and gas, Ministry of Energy and Mineral Resources Republic of Indonesia

Table 5.2 Protein yield calculation

Fishing vessel	Main catch	Edible portion	Protein content
PD vessel	Frigate and bullet tuna	58%	23.70%
	Mackerel	57%	20.40%
TN vessel	Prawn	57%	20.50%
HL vessel	Hairtail	59%	20.10%
LF vessel	Anchovies	62%	18.00%
	Prawn	57%	20.50%
	Sardine	65%	20.20%

Note: edible portion and protein content are taken from FAO (1989)

5.3.1.2 Result

Table 5.3 describes the annual data of each fishing vessel, which was generated from the profit model, as detailed in Appendix G. The table also presents the protein yield, which was estimated using the references in Table 5.2.

Based on the number of fishing days per year, it can be seen that TN and HL vessels have more fishing trips than other two vessels. In TN vessel this is primarily due to the flexibility to switch the operational mode from active to passive, in order to adjust to the seasonal patterns. Meanwhile, as the response to the seasonal changes, the HL operations are sometimes conducted during the daytime with a very limited trip. In contrast, the fishing operations in PD and LF vessels are not easily adjusting to the weather changes. Furthermore, in LF vessel the operations are stopped for at least six days per month during the full moon, because the bright moonlight prevents the fish from approaching the lamps installed under the LF platform. Despite the lower trip frequency, PD and LF vessels consume the significant amount of fuel per year, which is roughly ten times higher than the HL vessel. Generally, it can be seen that the pelagic fishing conducts fewer trips but consumes a significantly higher amount of fuel in contrast to demersal fishing.

Table 5.3 Annual production data for each studied vessel

Fishing vessel	The number of trips	Fuel		Catch		Value		Protein yield	
		diesel	petrol	kg	%	£	%	kg	%
PD vessel	218		22,080	58,060	37%	31,941	40%	7,408	40%
TN vessel	241	4,190		3,194	2%	6,488	8%	364	2%
HL vessel	236		2,255	4,182	3%	6,257	8%	493	3%
LF vessel	216	5,160	17,280	90,456	58%	34,977	44%	10,484	56%

Regarding fish production, both PD and LF vessels are targeting small pelagic fish, which migrate in large quantities. Hence, the amount of fish production by both vessels are significantly higher than other vessels targeting demersal fish. As seen in the Table 5.3, there is also a positive correlation between catch quantity, annual value and protein yield, which shows that pelagic fishing continually heads the chart regardless of the parameters. At this point, it can be said that pelagic fishing is noticeably more productive than demersal fishing.

The FUIs and ep-EROI analysis will further establish if the productivity of pelagic fishing is still leading relatively to fuel consumption and revenue. Figure 5.3 depicts the analysis results in relation to FUI_{kg}, $FUI_{£}$ and ep-EROI of the studied vessels. The FUI and ep-EROI analysis were calculated using the annual production data for a single vessel which was developed using defined input variables. Therefore, for comparison, another calculation which utilised data statistics from 2009-2015 has also been completed, and the result is presented in Figure 5.4.

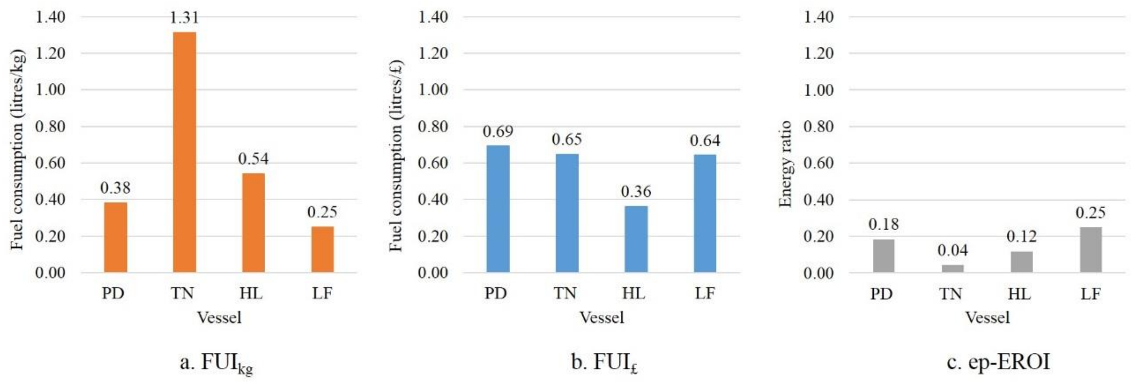


Figure 5.3 FUIs and ep-EROI of the studied vessels based on the annual production data

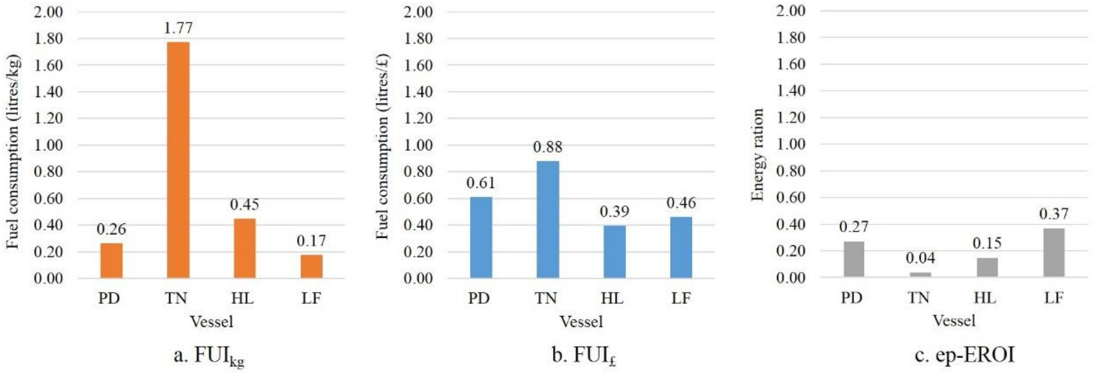


Figure 5.4 FUIs and ep-EROI of the studied vessels based on the 2009-2015 statistics

Both figures confirm a substantial amount of the catch from the PD and LF vessels have resulted in efficient vessel operations by showing a minimum FUI$_{kg}$. This means that the higher FUI$_{kg}$ in TN and HL vessels is also due to low catch volume, which contributes only 2-3% of the total catch. With regard to FUI$_{£}$, the lowest FUI$_{£}$ is clearly shown in the HL vessel. Furthermore the figure reveals that in the PD and LF vessels, FUI$_{kg}$ is higher than FUI$_{£}$ whose result is opposite to the TN and HL vessels.

The differences between FUI$_{kg}$ and FUI$_{£}$ indicate the value of the catch. In both PD and LF vessels, the FUI$_{£}$ is larger than its FUI$_{kg}$, which indicates that the operations produce a large catch of low value fish. On the other hand, when FUI$_{£}$ is smaller than FUI$_{kg}$, as seen in TN and HL vessels, it can be said that the vessels land valuable fish in spite of its low capacity. Accordingly, this FUI analysis suggests that in pelagic fishing which is specified by PD and LF vessels, to land 1 kg catch uses less fuel than to earn £1 revenue. On the other hand, in demersal fishing represented by TN and HL vessels, fuel efficiency in terms of revenue shows a better performance than in terms of catch quantity.

The value of ep-EROI value should be kept as high as possible. Hence, as illustrated in the figures, the LF vessel appears to be the leader by producing the highest result. This is not only because of the remarkable catch quantity but also the characteristics of the catch that produces more edible protein yield, as seen in Table 5.3.

The comparison between Figure 5.3 and 5.4 depict that both figures generally show the similar pattern. Nevertheless, the exception is found in FUI$_{£}$ for the TN vessel, which the vessel ranks differently in both figures. This dissimilarity is primarily due to data recorded in the statistics is lower than the ones gathered from the fishers, as seen in Table 4.4.

5.3.2 CO_2 emission analysis

Similar to the energy consumption analysis, this analysis is also calculated in the unit of kg catch and £ revenue. The following paragraphs describe the calculation method and the result.

The amount of CO_2 generated from the fishing operations was estimated using the generic emission factors published by the Indonesian Oil and Gas Agency (Lemigas, 2014). The emission factor used for the diesel fuel is 74.43 ton CO_2/TJ, whilst for the petrol is 72.97 ton CO_2/TJ. Using the references listed in Table 5.1 as well as Equation 5.1 and 5.2, the result of CO_2 analysis is presented in Figure 5.5.

CO_2 emissions were calculated based on annual fuel consumption, hence, in general the result shows the same configuration as FUIs. However, since the diesel fuel produce more CO_2 than petrol, a slight discrepancy is found in TN and LF vessels, which use respectively 100% and 30% diesel fuel.

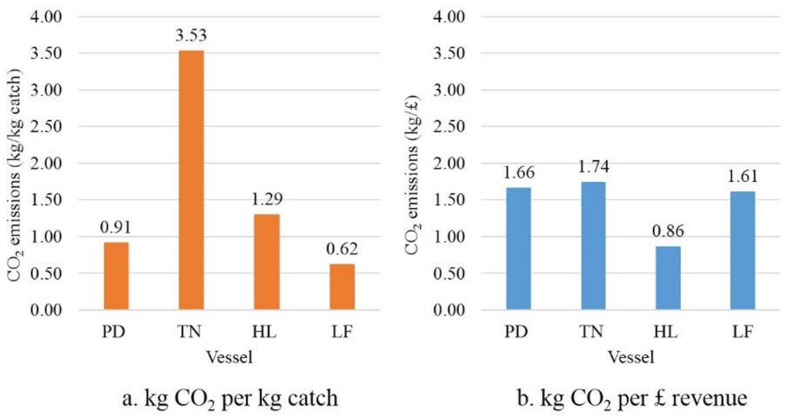


Figure 5.5 CO_2 emissions of the studied vessels

5.3.3 Environmental life cycle assessment

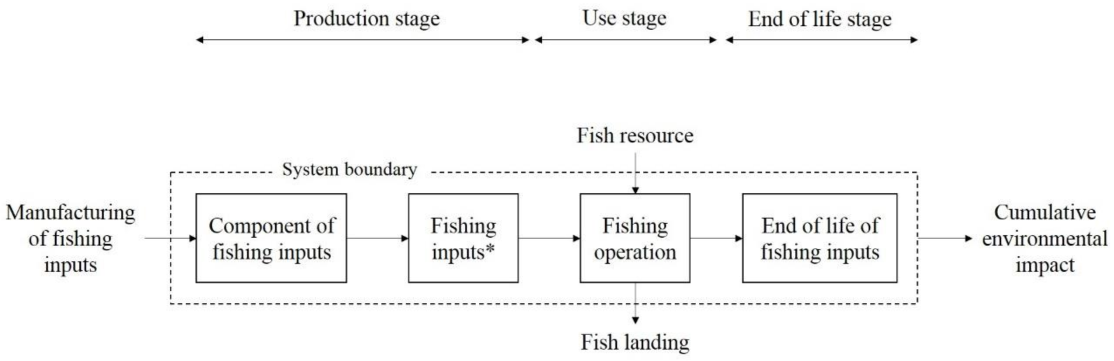
Whilst energy consumption and emissions analysis focus on fuel use, LCA considers the energy consumed throughout the lifetime of fishing vessels. This means both direct and indirect energy inputs will be included in the assessment. According to ISO 14040:2006, LCA is conducted in four phases, i.e. goal and scope definition, inventory analysis, impact assessment and result interpretation, as described in the following paragraphs.

5.3.3.1 Goal and scope

In this study, the LCA considers the fishing vessel as a fishing unit consisting of fishing attributes, a collection of inputs and outputs of fishing operations, as mentioned in Section

3.5. Regarding the scope analysis displayed in Figure 5.1, therefore the LCA will assess the environmental impact resulting from the life cycle of each input used within that boundary. Furthermore, in order to provide comprehensive information, both inventory analysis and impact assessment will be presented per vessel unit and per FU.

Figure 5.6 shows the system boundary for the LCA proses, which integrates all fishing inputs listed in Section 3.5. Accordingly, the LCA incorporates multiproduct assessments. One fishing vessel primarily consists of the vessel itself, gear, engine, fuel container, fish container and fishing supplies, each of which has the cycle as seen in Figure 3.6. This means the LCA requires enormous data, and since the data availability is limited various exclusions were applied during the assessment, as listed below.



* Breakdown of fishing inputs can be seen in Table 3.4 (PD vessel), Table 3.5 (TN vessel), Table 3.6 (HL vessel) and Table 3.7 (LF vessel).

Figure 5.6 System boundary of the study

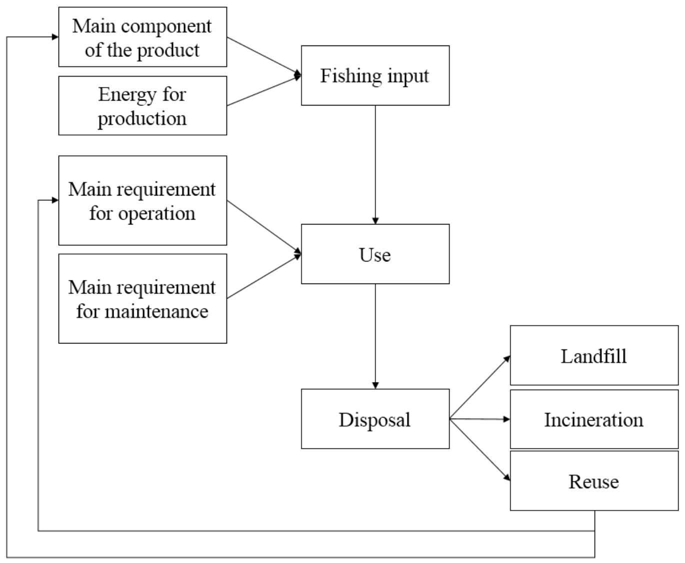


Figure 5.7 General life cycle of each fishing input

1. Each fishing input is analysed only based on the major components required during each stage. This means the following variables were omitted:

    a. Resource and energy associated with transportation due to data limitation and time restriction.

    b. Electricity consumption due to data unavailability and insignificant consumption. However, there is an exception for the production and maintenance of the fishing vessel and ice production.

    c. The production of solid waste and emissions due to data unavailability. However, an exception is applied for CO_2 emissions generated from vessel operation, which have been calculated in Section 5.3.2

2. Resource and energy required for engine production and end of life stages is omitted for all types of the fishing vessel as no information related to engine production was available. There are references relating to diesel engines published by Reenaas (2005) and Jiang et al. (2014), which are applicable for the case of diesel-powered vessel, however, since each vessel uses a different type of engine, including the engine in only one vessel would lead to a biased comparison. Regarding end of life, used or broken engines are typically sold on the second-hand market, therefore, it can be assumed to be 100% reused. The engine acquisition and its residual value will be calculated in the economic impact assessment.

3. In the case of inadequate and uncertain information, available LCA result published by other researchers were used, such us lamps (Ramroth, 2008), and wood adhesive (Nilsson, 2000).

As with the energy consumption and emission analysis, total catch and revenue data provided in Table 5.3 will be used instead of allocation per fish species. Furthermore, life cycle data for each fishing input was collected by means of interviews with the stakeholders comprising fishers, suppliers and boat builders and where possible, data was also gathered from the product information sheets published by the manufacturers. Regarding end of life treatment, assessments were made based on the way fishers handle the fishing attributes when their lifetime is over. Different treatments are specified depending on the type of product. For example, most of the wood from the vessels will be reused or sold to the second-hand market, whilst most of the nets will be sent to landfill. The proportion for each treatment is estimated based on the fisher's judgment.

In this study, the LCA was calculated using the IMPACT2002+ method which is run by SimaPro Classroom v8.5.2.0. Data for the background process (the production of generic materials, energy, transport, and waste management) for each component of the product was primarily obtained from Ecoinvent 3 database, with small portions carried out using Industry data 2.0 and European Life Cycle Database (ELCD) databases. In order to ensure an even comparison between the four vessels, the same background process was used across the fishing types. For example, sawn wood in any vessel used the same Ecoinvent 3 database. There are extremely limited processes that are based on Asia explicitly. Therefore, this study used the background processes that are based on the valid average for every country in the world or the rest of the world, which in the Ecoinvent data base it is denoted as GLO and RoW respectively. The justification for this calculation method has been explained in Section 2.6.2.

The cumulative environmental impact is presented using both midpoint and endpoint results. Whilst the midpoint categories are produced from the characterisation process, the latter is from the damage assessment (see Table 2.2). Regarding the sustainability assessment, the calculation is carried out using the endpoint categories. As those impacts are expressed in different units, the value is converted into ecopoints, using the normalisation and weighting method defined in IMPACT 2002+. Originally ecopoint is denoted as Pt, however due to the small fraction that found, milli-ecopoint is used denoted as mPt.

5.3.3.2 Inventory analysis

Inventory analysis lists the components and quantity required for each fishing input. For example, the production of a wooden boat used in the PD vessel requires 7.5 tons of wood, 33 kg painting material, and 290 kWh of electricity. This section encapsulates the result of the inventory analysis, which is provided in Appendix I, by presenting inventory per fishing vessel, inventory per FU and inventory per life cycle stage.

According to Table 3.4 – 3.7, fishing inputs considered in this study are the vessel, fishing gear, engine, fish container, fuel container, lamps and supplies. In terms of vessel material, PD, TN and LF vessels are wooden boats, whilst the HL vessel is a fibreglass boat. Furthermore, based on its size, the LF vessel is the largest, followed by PD, TN and HL vessels. Both PD and HL vessels are powered by an outboard engine, whilst TN and LF vessels use an inboard engine. A generator is also used in HL and LF vessels to produce electricity during night-time. Regarding the gear, each vessel uses a fishing net, except the HL vessel which uses hook and line. Furthermore, the LF vessel uses ten sets of fishing gear, whilst in contrast, other vessels only use one or two sets of gear. Both the vessel and the gear are maintained periodically, therefore, materials required for maintenance activities were included in the inventory. Furthermore, oil changing for engine maintenance was also considered, despite the exclusion of engine production and end of life process from the calculation. Different types of container are used to store the catch on board. Both TN and HL vessels use expanded polystyrene (EPS) cool boxes, PD vessel uses plastic drums, whilst the LF vessel uses bamboo baskets. For fuel storage, each vessel uses plastic containers in different sizes and capacities. According to Table 5.3, both PD and LF vessels consume a considerably more fuel than the other vessels. In addition, the PD vessel also carries twice as much ice as the supplies brought by the TN and HL vessels. Meanwhile, ice is not required in the LF vessel.

1. Inventory per vessel

   The outputs of the fishing vessel is extremely uncertain, thus, two vessel might have the similar inventory yet significantly different outputs. The inventory information for the whole vessel can subsequently be compared with the inventory per FU. Besides, it will make easier for the readers to follow and refer the calculation for further work.

   The inventory result is presented in kg, which indicates the mass contribution toward the impact. Furthermore, each input has a different lifetime, for example in PD vessel, the lifetime of the vessel is 20 year, fishing gear is 10 years and the fish container is 5 years. Therefore, the inventory is presented on an annual basis, as illustrated in. Figure 5.8. The figure shows the mass contribution per vessels as accumulated from fishing inputs, which is characterised by different colours. The lesser inputs result in the smaller mass contribution.

   In each vessel, the operational supplies are responsible for the most substantial input followed by the vessel itself, except in the case of the LF vessel, where the percentage of fishing vessel contribution is significantly smaller than the gear. The contribution of the engine, fish container, fuel container and lamps are insignificant, as seen in the graph, as none of their colour appear.

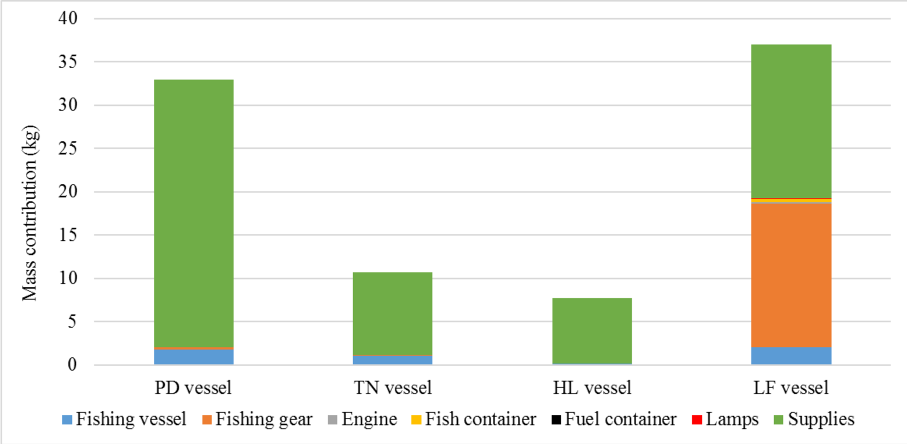


Figure 5.8 Result of inventory analysis for LCA per vessel per year (kg)

It is clearly seen that the LF vessel has the greatest input, whilst the HL vessel has the least. Operating the smallest boat made of fibreglass and using lightweight fishing gear has made the HL vessel the lightest fishing unit. The total mass contribution will be calculated per FU next.

2. Inventory per FU

Figure 5.9 shows the inventory result listed in two FUs i.e. per kg catch and per £ revenue. Similar to FUIs analysis, in the PD and LF vessels, the inventory per kg catch is less than the inventory per £ revenue, whilst the TN and HL vessels show the opposite result. Furthermore, the figure reveals that using both FUs, the TN and HL vessels require more inputs than the PD and LF vessels. Therefore, this analysis suggest that in general pelagic fishing operations require less inputs than the demersal fishing operations.

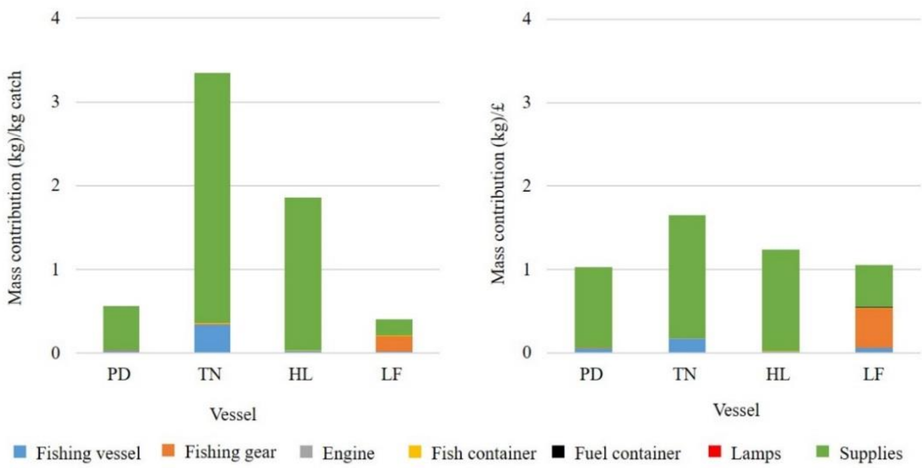


Figure 5.9 Result of inventory analysis per FU (kg/kg catch and kg/£ revenue)

When the fuel is the only considered input, the lowest $FUI_{£}$ is found in the HL vessel (Figure 5.3). However, when all supplies are included, the HL vessel ranks in third place after the PD and LF vessels. This is primarily because of the substantial amount of ice brought by the HL vessel. The ratio of ice and catch in HL vessel is roughly 1:1, in the PD vessel is 1:2.5, whilst no ice is required for the LF vessel.

3. Inventory per life cycle stage

Each fishing input has its own lifetime, hence the inventory includes the production, use, maintenance and end of life stages. Table 5.4 summarises the composition of the inventory result from each fishing input at different stages. Given the operating supplies are the major inputs for the fishing operation, the use stage takes the largest proportion in each vessel. Generally, it is followed by end of life, maintenance and production stages, leaving other stages with minor contribution. This result is in line with the study conducted by Fréon *et al.* (2014), which focused on the assessment of an anchovies fishing fleet. The study reveals that the largest mass contribution was derived from the use stage (69.50%), followed by end of life (9.60%), maintenance (6.70%) and production (2.90%).

Table 5.4 Result of inventory analysis per life stage (%)

Life stage	Fishing attributes	PD vessel	TN vessel	HL vessel	LF vessel
1) Production	Fishing vessel	1.18%	2.19%	0.35%	1.26%
	Fishing gear	0.05%	0.03%	0.01%	12.03%
	Fish container	0.02%	0.11%	0.15%	0.54%
	Fuel container	0.00%	0.01%	0.00%	0.04%
	Lamps	-	-	0.00%	0.01%
2) Use - supplies	Fuel	50.09%	32.86%	21.72%	46.62%
	Lubricant	1.99%	0.00%	0.27%	1.41%
	Ice	41.71%	56.45%	76.10%	0.00%
3) Use - maintenance	Fishing vessel	1.51%	2.82%	0.35%	1.53%
	Engine	0.07%	0.24%	0.14%	0.35%
	Fishing gear	0.30%	0.12%	0.03%	10.39%
4) End of life	Fishing vessel	2.69%	5.01%	0.70%	2.79%
	Fishing gear	0.35%	0.03%	0.01%	22.43%
	Fish container	0.02%	0.11%	0.15%	0.54%
	Fuel container	0.00%	0.01%	0.00%	0.04%
	Lamps	-	-	0.00%	0.01%

The maintenance stage contributes higher inputs than the production stage in the PD and TN vessels, whilst the opposite result are shown in the HL and LF vessels. This is principally because the HL vessel is a fibreglass vessel equipped with hook and line gear which is known for its low maintenance. In addition, boat maintenance in the LF vessel is less frequent than other wooden vessels (3 times/year compared to 4 times/year). At this point, the inventory result is done. Subsequently, it will be used to calculate the environmental impact, which is described in the next section.

5.3.3.3 Impact assessment and result interpretation: midpoint results

The midpoint result is presented in 15 categories with different unit of measurement as seen in Table 5.5. The table compares the result per vessel/year and it can be seen that both PD and LF vessels are responsible for the larger impacts than their counterparts. In contrast, in terms of impact per kg fish, TN and HL vessels contribute more impact than other vessels as seen in Table 5.6. Furthermore, Table 5.7 shows midpoint results in relation to £ revenue which confirm that HL vessel produces the slightly less impact than other vessels.

Regarding the fishing inputs, supplies are the major contributor for environmental impact in all vessels, followed by the fishing vessel itself. Further details of the midpoint result for each vessel is provided in Appendix J, whilst details about the contribution of each fishing input is discussed in the endpoint result, as seen in the next section.

Table 5.5 Impact assessment result in the midpoint categories per vessel per year

No	Impact categories	Unit	PD vessel	TN vessel	HL vessel	LF vessel
1	Carcinogen	kg C_2H_3Cl eq	3,128.21	55.30	333.87	2,601.25
2	Non-carcinogen	kg C_2H_3Cl eq	193.97	46.50	33.16	241.84
3	Respiratory inorganic	kg $PM_{2.5}$ eq	50.07	17.29	14.68	21.40
4	Ionizing radiations	Bq C-14 eq	465,449.89	92,499.13	48,516.41	479,953.02
5	Ozone layer depletion	kg CFC-11 eq	0.01	0.00	0.00	0.01
6	Respiratory organics	kg C_2H_4 eq	23.17	3.53	2.54	23.68
7	Aquatic ecotoxicity	kg TEG water	2,676,603.26	573,223.32	316,681.99	2,663,683.65
8	Teresstrial ecotoxicity	kg TEG soil	567,100.60	117,891.61	62,189.05	574,181.99
9	Terrestrial acidification/nutrification	kg SO_2 eq	343.08	71.68	45.71	334.89
10	Land occupation	m^2org.arable	480.71	239.50	29.00	548.79
11	Aquatic acidification	kg SO_2 eq	129.43	25.45	16.30	124.84
12	Aquatic eutropication	kg PO_4 P-lim	6.76	1.62	0.96	6.87
13	Global warming	kg CO_2 eq	15,614.79	3,072.92	2,227.59	15,270.98
14	Non-renewable energy	MJ primary	1,078,184.45	218,714.09	116,796.42	1,132,444.26
15	Mineral extraction	MJ surplus	489.40	119.31	59.95	609.47

Table 5.6 Impact assessment result in the midpoint categories per kg fish

No	Impact categories	Unit	PD vessel	TN vessel	HL vessel	LF vessel
1	Carcinogen	kg C_2H_3Cl eq	0.05	0.02	0.08	0.03
2	Non-carcinogen	kg C_2H_3Cl eq	0.00	0.01	0.01	0.00
3	Respiratory inorganic	kg $PM_{2.5}$ eq	0.00	0.01	0.00	0.00
4	Ionizing radiations	Bq C-14 eq	8.02	28.96	11.60	5.31
5	Ozone layer depletion	kg CFC-11 eq	0.00	0.00	0.00	0.00
6	Respiratory organics	kg C_2H_4 eq	0.00	0.00	0.00	0.00
7	Aquatic ecotoxicity	kg TEG water	46.10	179.50	75.73	29.45
8	Teresstrial ecotoxicity	kg TEG soil	9.77	36.92	14.87	6.35
9	Terrestrial acidification/nutrification	kg SO_2 eq	0.01	0.02	0.01	0.00
10	Land occupation	m^2org.arable	0.01	0.07	0.01	0.01
11	Aquatic acidification	kg SO_2 eq	0.00	0.01	0.00	0.00
12	Aquatic eutropication	kg PO_4 P-lim	0.00	0.00	0.00	0.00
13	Global warming	kg CO_2 eq	0.27	0.96	0.53	0.17
14	Non-renewable energy	MJ primary	18.57	68.49	27.93	12.52
15	Mineral extraction	MJ surplus	0.01	0.04	0.01	0.01

Table 5.7 Impact assessment result in the midpoint categories per £ revenue

No	Impact categories	Unit	PD vessel	TN vessel	HL vessel	LF vessel
1	Carcinogen	kg C_2H_3Cl eq	0.10	0.01	0.05	0.07
2	Non-carcinogen	kg C_2H_3Cl eq	0.01	0.01	0.01	0.01
3	Respiratory inorganic	kg $PM_{2.5}$ eq	0.00	0.00	0.00	0.00
4	Ionizing radiations	Bq C-14 eq	14.57	14.26	7.75	13.72
5	Ozone layer depletion	kg CFC-11 eq	0.00	0.00	0.00	0.00
6	Respiratory organics	kg C_2H_4 eq	0.00	0.00	0.00	0.00
7	Aquatic ecotoxicity	kg TEG water	83.80	88.35	50.61	76.16
8	Teresstrial ecotoxicity	kg TEG soil	17.75	18.17	9.94	16.42
9	Terrestrial acidification/nutrification	kg SO_2 eq	0.01	0.01	0.01	0.01
10	Land occupation	m^2org.arable	0.02	0.04	0.00	0.02
11	Aquatic acidification	kg SO_2 eq	0.00	0.00	0.00	0.00
12	Aquatic eutropication	kg PO_4 P-lim	0.00	0.00	0.00	0.00
13	Global warming	kg CO_2 eq	0.49	0.47	0.36	0.44
14	Non-renewable energy	MJ primary	33.76	33.71	18.67	32.38
15	Mineral extraction	MJ surplus	0.02	0.02	0.01	0.02

5.3.3.4 Impact assessment and result interpretation: endpoint results

The total impact for one vessel is an aggregation of impacts from fishing inputs, each of which consists of three life cycle stages and four endpoint categories, as illustrated in Figure 5.10. Regarding the presentation, the total impact can be depicted either based on the fishing input, life cycle stage or impact categories. Since this study concerns on the contribution of fishing vessel operation toward environmental quality, the total impact will be described based on the impact categories. As with the inventory analysis, the explanation will be divided into 3 parts, i.e. total impact per vessel, per FU and per life cycle stage. It is important to note that the assessment result indicates a drawback to the environment, which means the lower point is the better.

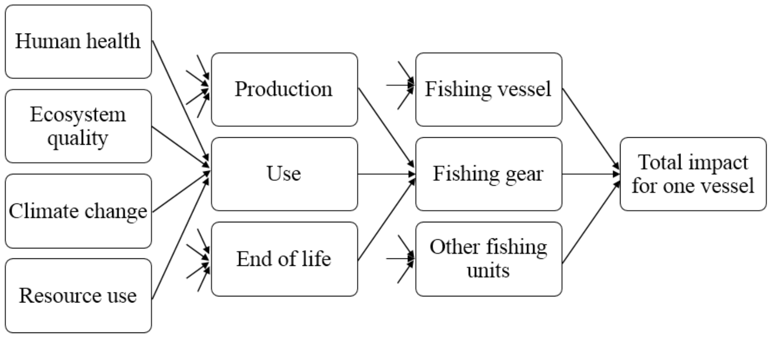


Figure 5.10 Calculation scheme for impact assessment

1. Total impact per vessel

   Figure 5.11 illustrates the total impacts of the four studied vessels based on impact categories. It can be seen that most of the impacts are associated with human health and resource use, followed by climate change and ecosystem quality.

   Impacts on human health are responsible for the most significant percentage in the TN and HL vessels followed by impact on resource use. Conversely, in the PD and LF vessels, impacts on resource use share the most extensive portion leaving the contribution to human health in the second place. The assessment result shows that ice consumption has a significant impact on human health, which is predominantly derived from electricity consumption during the production stage. Meanwhile, fuel consumption greatly contributes to resources use as the fuel is produced from natural resources. As seen in Table 5.4, the percentage of ice consumption in both TN and HL vessels is larger than the fuel, whilst the opposite result is shown in PD and LF vessels.

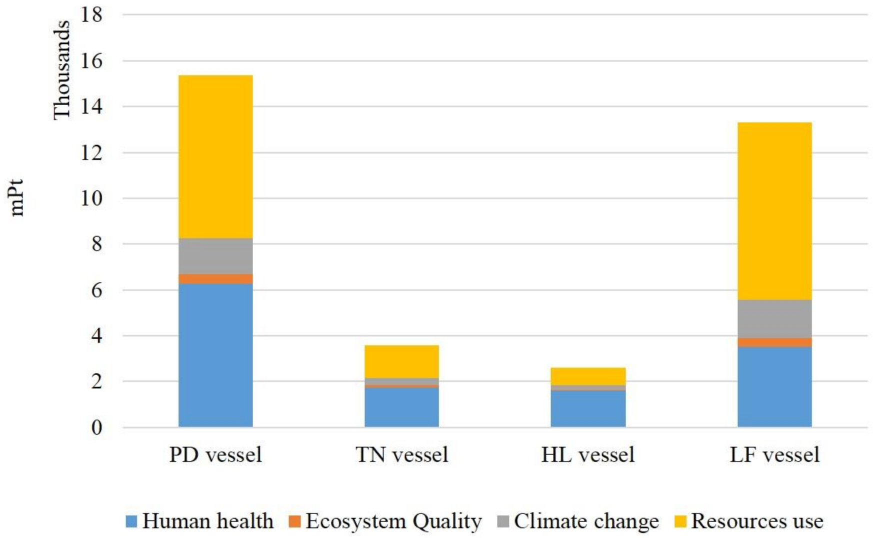


Figure 5.11 LCA results per vessel per year (mPt)

The highest impact is derived from the PD vessel, followed by the LF, TN and HL vessels respectively. In fact, examining Figure 5.8, the total fishing inputs accumulated from the PD vessel is slightly lower than the LF vessel. This difference suggests that even though the PD vessel use less fishing inputs than the LF vessel, it produces a higher impact than its counterpart. This is primarily because of the ice use in the PD vessel, which is not applied in the LF vessel.

2. Total impact per FU

Figure 5.12 demonstrates the impact per kg and £ revenue, which is generally in line with the inventory result (Figure 5.9). Firstly, both TN and HL vessel, which operate demersal fishing, produce more impact per kg catch than per £ revenue, whilst the PD and LF vessels, as the representative of pelagic fishing, perform reversely. Secondly, demersal fishing generates higher environmental impacts than pelagic fishing.

3. Total impact per life cycle stage

In terms of the life cycle stage, Table 5.8 summarises the contribution of each fishing input to the environmental impacts. It should be noted that the percentage presented in the table is based on the total impact aggregated of from four impact categories. Detailed results describing the value for each category are provided in Appendix J.

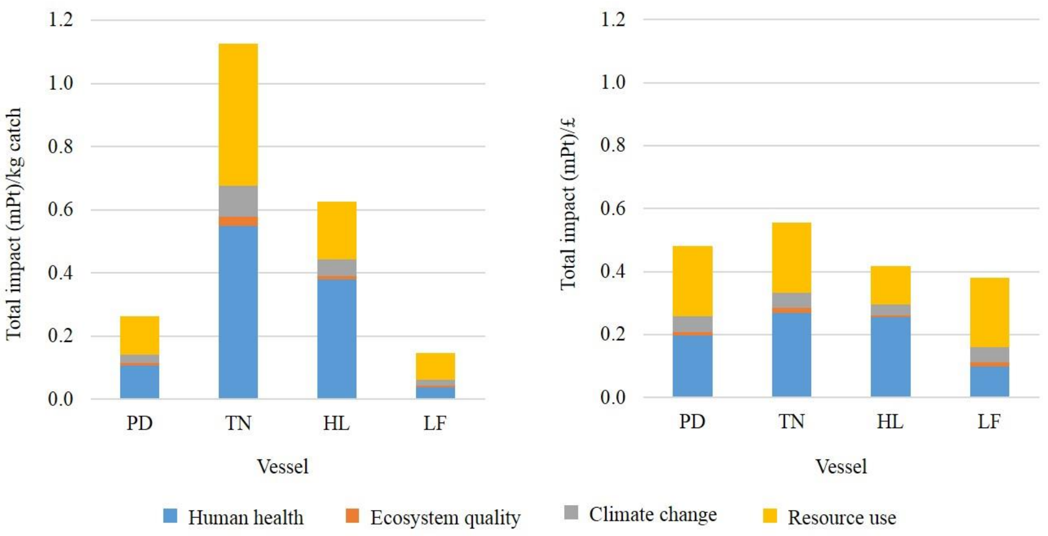


Figure 5.12 LCA results in different FU (mPt/kg catch and mPt/£ revenue)

Table 5.8 LCA result per life stage (%)

Life stage	Fishing attribute	PD vessel	TN vessel	HL vessel	LF vessel
1) Production	Fishing vessel	0.48%	1.39%	1.31%	0.61%
	Fishing gear	0.17%	0.23%	0.02%	7.29%
	Fish container	0.08%	0.56%	0.77%	0.01%
	Fuel container	0.01%	0.05%	0.01%	0.06%
	Lamps	-	-	0.11%	0.52%
2) Use - supplies	Fuel	72.38%	52.45%	43.44%	82.90%
	Lubricant	3.67%	0.00%	0.69%	3.36%
	Ice	20.79%	38.97%	52.41%	0.00%
3) Use - Maintenance	Fishing vessel	1.77%	5.06%	0.58%	1.93%
	Engine	0.13%	0.53%	0.35%	0.83%
	Fishing gear	0.30%	0.29%	0.16%	1.25%
4) End of life	Fishing vessel	0.17%	0.46%	0.14%	0.24%
	Fishing gear	0.04%	0.01%	0.00%	0.97%
	Fish container	0.01%	0.00%	0.00%	0.03%
	Fuel container	0.00%	0.00%	0.00%	0.00%
	Lamps	-	-	0.00%	0.00%

The table shows that the use stage is generating the most significant impact. In the PD and TN vessels it is followed by the maintenance and production stages, whilst in HL and LF vessels production stage generate more impacts than maintenance stage. Furthermore, it can be seen that the impacts derived from end of life stage is insignificant (< 1%), which in fact, according to Table 5.4, this stage contributes a substantial amount of fishing inputs. This result is confirmed by Fréon *et al.* (2014) who argued that maintenance and production stages generate more impact than end of life stage, despite smaller inputs.

5.3.3.5 Uncertainties and limitations

Previously, it has been mentioned that the background process used to calculate the impact is obtained from a database that represents the global average and it is not explicitly in the Asian or Indonesian context. Accordingly, the result of this assessment deals with substantial uncertainty. Uncertainty analysis is not provided in the SimaPro classroom version, hence, the analysis cannot be performed in this study. Furthermore, there are also certain limitations that restrict the data collection process and cause to some omissions.

However, this study is aimed at comparing different fishing vessels operations from the same region with the focus on providing an equal assessment of the studied vessels.

Therefore, despite some existing limitations, it is reasonable to argue that by using the consistent data inputs, this study is able to present a proportional and valid comparison.

5.4 Economic impacts

5.4.1 Profit analysis

In Section 4.2, the profit model has been developed to illustrate the fluctuation of monthly profit in a one year period for different stakeholders and describe the cost distribution. In this section, the analysis will be focused on the annual profit gained by the owner as the main investor, in addition to the income of the fishers and the skipper who conduct the fishing operations. Knowing that the sharing system does not properly follow the regulation (see Section 4.2.4), the main purpose of this analysis is to investigate which operation offers a better share from each individual's perspective. Therefore, in order to provide an equal comparison, the profit is presented relatively to the total revenue of each vessel, as seen in Table 5.9.

Regarding the owner's share, the highest share is found in the TN vessel, whilst the smallest is in the PD vessel. Furthermore, the owner's share is higher than the fishers, except for the HL vessel. This difference does not indicate unfairness in other three vessels, because the owners still have responsibility for other costs.

The number of fishers involved in fishing affects the share obtained by each of them. As in the operation in PD and LF vessels involves at least 10 fishers, the smallest share for a single fisher is found in them. In contrast, the highest share is in HL vessel, which on average is crewed by 1-2 persons. Furthermore, in the LF vessel, the skipper receives a slightly higher share than the fisher since different sharing system is applied. Meanwhile, in the remaining vessels the same share is applied.

Table 5.9 Different stakeholder's shares in the studied vessels

Share	PD vessel	TN vessel	HL vessel	LF vessel
Owner	18%	39%	21%	36%
Fisher	3%	13%	21%	3%
Skipper	3%	13%	21%	4%

Note: the percentage is calculated from total revenue

5.4.2 Life cycle cost assessment

In line with LCA, LCC estimates total cost throughout the fishing vessel's lifetime including its fishing attributes. The analysis was also conducted in four phases, i.e. goal and scope definition, inventory analysis, impact assessment and result interpretation.

5.4.2.1 Goal and scope

Given the specific concern on economic aspects, this LCC is intended to depict the cost distribution throughout the vessel's life time. As the continuation of the LCA, the scope of the assessment and FU are the same as the ones defined for LCA study (Section 5.3.3.1). Hence, the discussion in this section focuses on data collection and analysis.

All fishing inputs and outputs considered in the LCA were economically calculated in the LCC using 2015 prices. As with the LCA, data related to the transportation of those items from the manufacturer, store or dockyard to the port were omitted. However, whilst the environmental load from the engine was neglected, its monetary value was included in the LCC. Regarding end of life, it was assumed that no cost was required to demolish the fishing inputs, as no particular mechanism was applied for waste treatment. Instead, the residual value attached to the fishing inputs that are saleable on the second-hand market was included in the calculation.

As mentioned in Section 2.6.3, the cost component of this LCC included CAPEX, OPEX, and DISPEX and the calculation is applied for each fishing input. Firstly, CAPEX are associated with the purchasing prices of the fishing inputs. Subsequently, OPEX consists of supplies costs, personnel costs, selling costs, and maintenance costs. Lastly, DISPEX is the residual value at the end of each item's life. Most of them are zero-valued, except the vessel and engine.

The costs were estimated based on the information gathered from fishers, boat builders, suppliers and vendors. Furthermore, the magnitude of personnel and selling costs depend on the total revenue, and it was obtained from the profit model.

The period of analysis is 20 years, this being the average of vessels' lifetimes. Consequently, all the costs are adjusted to maintain for 20 years of operation, and include with some uncertainties. Therefore, further assumptions were made, as listed below.

1. Future income should be estimated in order to predict the personnel and selling costs throughout the studied year. Thus, the fish production was assumed to

decrease by 2% per year, according to the decreasing trend showed in the statistic reports.

2. The number of fishing inputs, maintenance costs per task, fishing supplies per trip and the number of fishers per vessel remained constant.

3. Price changes throughout the studied year were estimated using the inflation rate.

In order to ensure that the present cost is accurate, the information for each vessel was gathered from several respondents. Most data revealed similar values. When a significant difference was found, respondents were asked to explain their reasons and their opinion about the conflicting data. In the end, the cost variables entered into the LCC were the ones which is agreed by the relevant respondents.

SimaPro provides a feature which allows the LCC calculation to be performed in accordance with LCA. However, the tools for modelling the process are not provided in the SimaPro classroom version. Hence, LCC analysis was performed separately using Microsoft Excel, in the following steps.

1. Future value conversion

   All the cost information is at present value (*PV*). However, the prediction of the future value (*FV*) is required in LCC, as it involves forthcoming expenditure, which is unequal to the present expenditure. Therefore, inflation should be considered. Inflation reduces the value of the product as a result of a gradual price increase through time. The inflation rate (*inf*) is defined based on the rate of the Bank of Indonesia, which was assumed to be constant at 7.08%. The *FV* was estimated using Equation 5.4, where *n* is the number of years.

$$FV = PV.(1 + inf)^n$$

Equation 5-4

2. Present value conversion

   Expenses spent at a different time cannot be compared directly due to the varying time value of money. Therefore, it has to be returned back to the *PV* using a discount factor (*Dis*), which is defined as the opportunity cost that could be obtained if the money is invested differently. In this study, the *FV* was discounted using the average interest rate from the Bank of Indonesia i.e. 4.53% (Equation 5.5).

$$PV = \frac{FV}{(1 + Dis)^n}$$

Equation 5-5

3. Aggregating the result

   LCC values the present and future money equally by converting all cost into common currency and adding it up to obtain the total value (Davis *et al.*, 2005), as described in Equation 5.6. In this study, all the cost was calculated in Indonesian Rupiah (Rp), and for final presentation, it was converted into British pound sterling (£) using the fixed exchange rate (1£ = Rp16,555).

$$LCC = C_0 + PV_{recurring} - PV_{residual}$$

Equation 5-6

Where:

C_0 = initial investment

$PV_{recurring}$ = present value of all repeating expenses, including supplies, maintenance and personnel cost)

$PV_{residual}$ = present value of residual value at the end of the lifetime

5.4.2.2 Inventory analysis

Whilst the inventory in the LCA recorded all fishing inputs required throughout the vessel's lifetime, the inventory in the LCC listed the cost associated with those inputs. The fishing inputs considered in the LCC is the same as LCA. However, two additional costs were added in the LCC, i.e. personnel and selling costs. In order to calculate LCC, all recorded costs were subsequently projected into a 20 year period using the inflation rate and it was discounted back to the present value. As a result, the pattern of LCC inventory and LCC result will be identical. Therefore, the inventory result is not presented in this section, although the details can be seen in Appendix K.

5.4.2.3 Impact assessment and result interpretation

Impact in this LCC refers to the total cost spent to operate the fishing vessel throughout its lifetime. In line with LCA, the LCC result is presented per vessel and per FU and per life cycle stage, as described below.

Figure 5.13 shows the LCC result per vessel. Due to various recurring expenses, and the requirement to adjust with the annual production data, the costs were calculated on an annual basis, and are presented in £. It can be seen that there is a significant difference between costs spent on pelagic fishing (PD and LF vessels) and demersal fishing (TN and HL vessels), which are predominantly due to the substantial discrepancy in supplies and personnel costs. In Section 2.4.4, it was noted that supplies and personnel costs have the most substantial effect on annual profit. When all economic values associated with other fishing inputs are considered, both these expenses are still highest in all vessels.

Furthermore, by excluding personnel and selling costs, the LCC result is identical with the inventory in the LCA (Figure 5.8), which means that in general, the fishing inputs in the kg unit is linear to the inputs in monetary unit. However, when both items are incorporated, it can be seen that higher personnel cost in the PD vessel increases the total cost so that exceeds all other vessels, even the LF vessel which consists of ten platforms.

Subsequently, Figure 5.14 shows the total cost per FUs (kg catch and £ income). As with to the previous analysis, low catch quantity in the TN and HL vessels continually ranks them as the costliest operations. In terms of kg catch, the cost contribution in each vessel is remarkably diverse, however, it shows little different in terms of £ income, which indicates that in order to produce £1 of revenue, the cost spent in each vessel is nearly the same, regardless of the fishing method used.

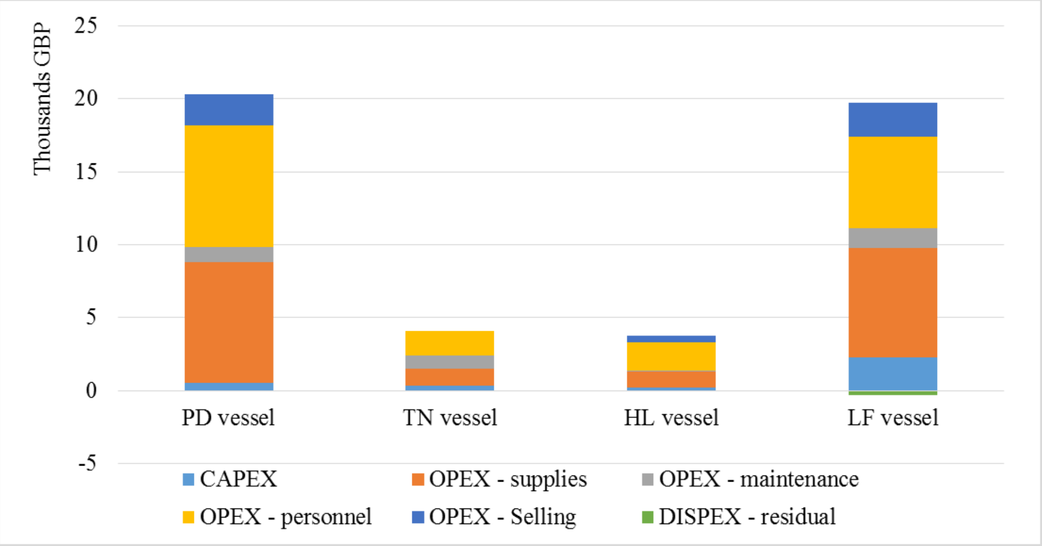


Figure 5.13 LCC result per vessel per year (thousands GBP)

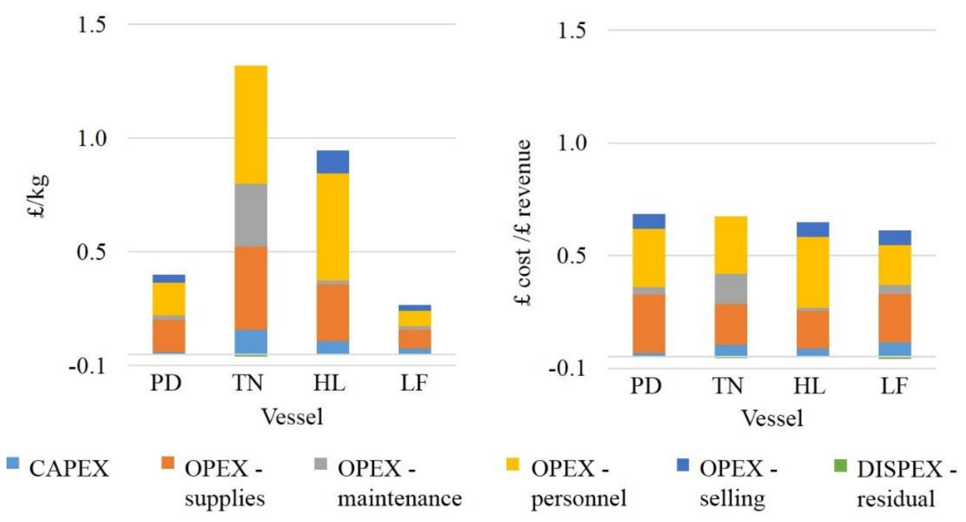


Figure 5.14 LCC results in different FU (£/kg catch and £/£ revenue)

Concerning the life cycle stage of the fishing vessels, Table 5.10 shows that the largest expenses are established in the use stage (OPEX), specifically supplies, personnel and selling cost, which is then followed by the maintenance cost. The figure shows that the percentage of maintenance cost in the TN vessel is considerably higher than other vessels, which is primarily due to the fishing gear. The gear used in the TN vessel is changed every year, because of physical damage. The gear in the HL vessel also requires frequent replacement, however, seeing that it is inexpensive, the maintenance cost is not significantly affected.

Residual value is gathered from the engine, vessel and gear prices when sold on the second-hand market. Hence, it results an additional value, which reduce the total LCC. It can be seen that the percentage is extremely small. Buying a used boats and engines is common in the region, even though they are not always in excellent condition, as there will be buyers who are ready to make modification or sell on specific parts that are reusable.

Fibreglass boats were introduced into the region in 2008, so all the boats are less than 10 years old. In this case, the residual value was estimated based on the price from other regions with a similar boat design and size. Compared to other wooden vessels, the residual value of the fibreglass boat is lesser. It is only 25% of the new vessel's price, whilst for other vessels, it is more than 40%. A detailed calculation of the LCC for each vessel is provided in Appendix L.

Table 5.10 LCC result per life cycle stage (%)

Life stage		PD vessel	TN vessel	HL vessel	LF vessel
1) Production - Investment	Fishing vessel	0.27%	0.86%	0.86%	0.33%
	Engine	1.21%	3.65%	2.13%	0.51%
	Fishing gear	0.28%	0.97%	1.38%	6.56%
	Fish container	0.04%	1.43%	0.55%	0.44%
	Fuel container	0.01%	0.04%	0.01%	0.01%
	Lamps	-	-	0.08%	0.36%
2) Use - Operation	Supplies	37.57%	28.20%	25.28%	34.74%
	Personnel	44.64%	47.49%	56.44%	34.53%
	Selling	11.45%	0.00%	11.93%	12.81%
3) Use - Maintenance	Fishing vessel	1.64%	3.54%	0.36%	1.61%
	Engine	0.17%	0.62%	0.41%	0.96%
	Fishing gear	3.08%	14.16%	0.96%	8.30%
4) End of life	Fishing vessel	0.22%	0.57%	0.29%	0.33%
	Engine	0.09%	0.39%	0.10%	0.06%
	Fishing gear	0.04%	0.00%	0.00%	0.77%
	Fish container	0.00%	0.00%	0.00%	0.00%
	Fuel container	0.00%	0.00%	0.00%	0.00%
	Lamps	-	-	0.00%	0.00%

5.4.3 Financial analysis

After the total cost was identified in the LCC assessment, financial analysis was performed to investigate the feasibility of the fishing businesses from the owner's perspective. The analysis incorporates net present value (NPV), payback period (PP) and the internal rate of return (IRR). The NPV shows the present value of the future cash flow, which is useful for analysing the attractiveness of the investment. Furthermore, PP indicates the length of time to recuperate the investment cost and IRR is the annual growth rate of the investment. The projection of expenditure for a 20 year period generated during the LCC process was used to calculate these financial indicators.

5.4.3.1 Methodology

The calculation is performed using the following financial formulas:

$$NPV\ (i,n) = \sum_{i=0}^{n} \frac{C_i}{(1+dis)^n} - C_0$$

Equation 5-7

$$PP = \frac{\left(\sum C_{negative}\right)}{C_{positive}} + t$$

Equation 5-8

Where

C_i	= net cash inflow per year in year – i
C_0	= initial investment
$\Sigma C_{negative}$	= cumulative cash flow until the last negative value appears
$C_{positive}$	= net cash inflow, cumulative cash flow from when the first positive value appears
t	= the number of years which $\Sigma C_{negative}$ appears

Meanwhile, since IRR is the discount rate to produce zero NPV, the value is found by setting the NPV formula to zero.

5.4.3.2 Result

Figure 5.15 shows the result of financial analysis. It should be noted that the analysis is carried out in common, optimistic and pessimistic scenarios. The error bars indicate the NPV ranges for optimistic and pessimistic scenarios, whilst the range for other indicators can be seen in Appendix M.

As clarified in the figure, the NPV is positive in all vessels, which signifies that all studied operations are a viable business over a 20 year period. However, it can be negative if a pessimistic scenario is applied for PD and HL vessels, which suggests that the number of successful trips is a sensitive variable for financial success of both vessels. Furthermore, there is a significant difference between the NPV value in the LF vessel and the remaining vessels, which is primarily caused by the large discrepancy in the owner's profit, as illustrated in Figure 4.6. The figure also shows that the IRR value in all vessels is noticeably higher than the discount rate (7.08%), which confirms that fishing operations in all studied vessels is a worthwhile investment.

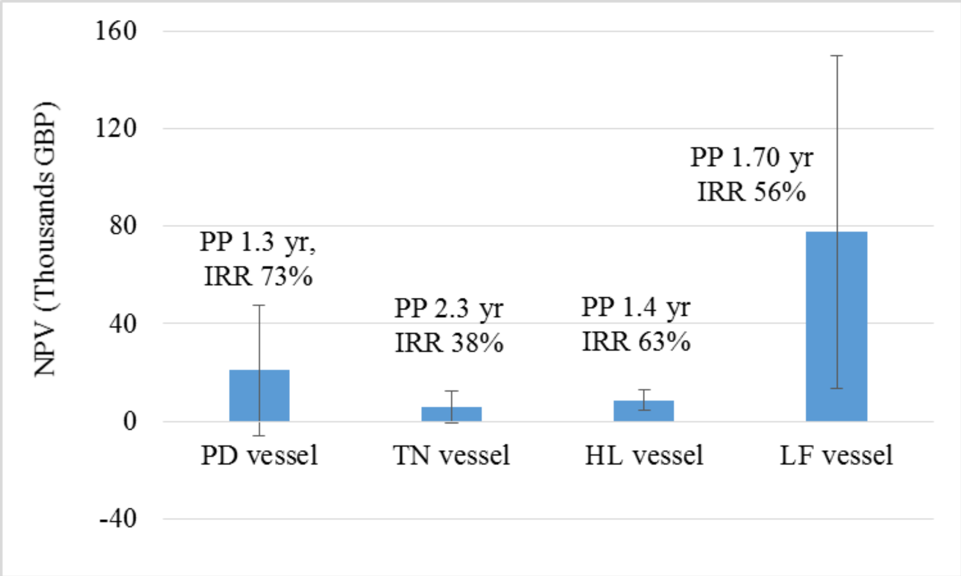


Figure 5.15 Summary of financial analysis of the studied vessels

Regarding PP, the result ranges between 1.3 and 2.3 years, with the longest time being found in the TN vessel. This is because the percentage of investment and maintenance costs in the TN vessel is the highest compared to other vessels. This result confirms that even though the owner of the TN vessel receives higher profit than the owner of the HL vessel (Figure 4.6), it is not necessarily in line with the long term economic performance.

5.4.3.3 Sensitivity analysis

Sensitivity analysis is an essential step in analysing the feasibility of the fishing investment. It is carried out by setting different scenarios to evaluate their effect on the cash flow. The viability of the fishing business is affected by numerous variables, such as the number of the trips and fuel consumption. However, not every variable easily changes or significantly affects the business. Therefore various scenarios were set using variables which potentially influence the cash flow. The following paragraphs summarise the result of the sensitivity analysis, which was carried out by changing the most influential variables which are the number of the trips (Table 5.11), fuel consumption (Table 5.12), fuel price (Table 5.13), catch quantity (Table 5.14), and fish price (Table 5.15). Further detail of the sensitivity analysis is provided in Appendix N.

Table 5.11 Comparison of sensitivity analysis on the change in the number of trips

Fishing vessel	Number of trips/month	NPV (£)			IRR		
		Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
PD vessel	Reduced by 20%	10,622	32,145	-10,898	51%	71%	0%
TN vessel		-25	5,080	-5,125	6%	34%	0%
HL vessel		5,699	9,071	2,328	47%	63%	29%
LF vessel		48,988	106,741	-2,392	40%	67%	5%

Table 5.12 Comparison of sensitivity analysis on the change in fuel consumption

Fishing vessel	Fuel/trip (litres)	NPV (£)			IRR		
		Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
PD vessel	Increased by 15%	-2,895	24,007	-29,796	12%	70%	0%
TN vessel		4,120	10,659	-2,410	33.06%	53%	0%
HL vessel		7,694	12,049	3,338	60.35%	80%	39%
LF vessel		63,993	138,316	-2,127	50.24%	85%	3%

Table 5.13 Comparison of sensitivity analysis on the change in the fuel price

Fishing vessel	Fuel price/litre (Rp)	NPV (£)			IRR		
		Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
PD vessel	Increased by 20%	-6,625	20,275	-33,529	#NUM!	65%	0%
TN vessel		3,527	10,113	-3059	31%	52%	0%
HL vessel		7,385	11,788	2,984	59%	79%	37%
LF vessel		63,993	138,316	-2,127	50%	85%	3%

Table 5.14 Comparison of sensitivity analysis on the change in the catch quantity

Fishing vessel	Catch/trip (kg)	NPV (£)			IRR		
		Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
PD vessel	Reduced by 15%	-11,597	11,269	-34,465	#NUM!	48%	0%
TN vessel		-572	5,028	-6,173	#NUM!	35%	0%
HL vessel		5,058	8,847	1,267	46%	64%	24%
LF vessel		42,414	105,911	-14,073	38%	69%	-12%

Table 5.15 Comparison of sensitivity analysis on the change in the fish price

Fishing vessel	Fish price/kg (Rp)	NPV (£)			IRR		
		Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
PD vessel	Reduced by 10%	-759	23,454	-24,971	8%	65%	0%
TN vessel		1,587	7,447	-4,271	22%	43%	0%
HL vessel		6,240	10,177	2,310	52%	71%	31%
LF vessel		54,197	120,591	-4,870	44%	75%	0%

The TN vessel operation is most susceptible to changes in the frequency of the fishing trips. As seen in Table 5.11, reduction of the fishing trips by 20% per month results in a meagre NPV in the TN vessel, whilst in other vessels, the reduction still produces viable cash flow. This result suggests that trip reduction in the TN vessel should be maintained.

Regarding the change in fuel consumption (Table 5.12), it can be seen that the increase in fuel by 15% in the PD vessel results in unviable financial situation. Since this study is concerned with environmental and economic performance, increasing in fuel will not considered further.

Table 5.13 shows the increase in fuel price, which significantly affects the feasibility of the PD vessel operation. This is because the supplies cost in the PD vessel is imposed on the owner, whilst in other vessels, the fuel cost is shared with the fishers.

Compared to other variables, the size of catch per trip is the most unpredictable one, and it changes over time. According to Table 5.14, it can be seen that PD and TN vessels are vulnerable operation regarding catch fluctuation. The fact that the catch rate in the TN vessel is already low suggests that any further reduction is undesirable since it does not only affect the financial situation but also energy efficiency.

The fish price fluctuation is highly dependent on the market situation. Table 5.15 reveals that compared to other vessels, decreasing the fish price in the PD vessel has a significant influence on the feasibility of the fishing business. This result suggests that the price of the fish production from PD vessel should be monitored to maintain the viability of the fishing operation.

5.5 Social impacts

5.5.1 Goal and scope

The goal of the assessment is to investigate the social impacts generated throughout the vessel’s lifetime. The assessment scope for this S-LCA is consistent with the LCA and LCC, as described in Figure 5.6. The S-LCA was conducted using qualitative data representing the social features within the fish production system. Therefore, unlike LCA and LCC, the inventory and result of the S-LCA were not expressed per functional unit.

Four stakeholder groups are included in the assessment, incorporating workers (fishers, skippers and port-based workers), value chain actors (vendors, vessel owners, fish sellers, fish buyers and second-hand goods buyers), local community (fisher’s wives, the youth and non-fishing community) and society (influential figures and local government). In the case of stakeholders who have overlapping roles in the fishing community, they were selected based on their main contributions.

Social impacts were represented in six impact categories, i.e. human rights, working conditions, health and safety, cultural heritage, governance, and the socio-economic repercussions. Each impact category is characterised by several subcategories which are referred to as a set of social attributes attached to the stakeholders, as detailed in Section 2.6.4. In this study, 24 subcategories were selected based on the suitability with the characteristics of the studied fishing community, and the classification method is presented in Table 5.16.

Subsequently, the final score was obtained from the multiplication of the gap and the weight, as seen in Figure 5.16. Due to limitations in relation to time and resources, the gaps were calculated by evaluating the performance of each subcategory against the reference points, whilst the weight is defined based on an equal weighting system, as described in Table 1.17

Table 5.16 Classification of subcategories into impact categories

Stakeholders	**Subcategories**	**Impact categories**
Workers	Child labour	Human rights
	Forced labour	
	Equal opportunities	
	Freedom of association and collective	Working conditions
	Fair salary	
	Working hours	
	Health and safety	Health and safety
	Social benefit/social security	
Local community	Delocalisation and migration	Cultural heritage
	Community engagement	
	Cultural heritage	
	Respect for indigenous rights	
	Access to immaterial resources	
	Access to material resources	
	Safe and healthy living conditions	Socio-economic repercussions
	Secure living conditions	
	Local employment	
Society	Prevention and mitigation of conflict	
	Contribution to economic development	
Value chain actors	Suppliers relationship	
Society	Public commitment to sustainability issues	Governance
	Free from corruption	
	Development of technology	
Value chain actors	Fair competition	

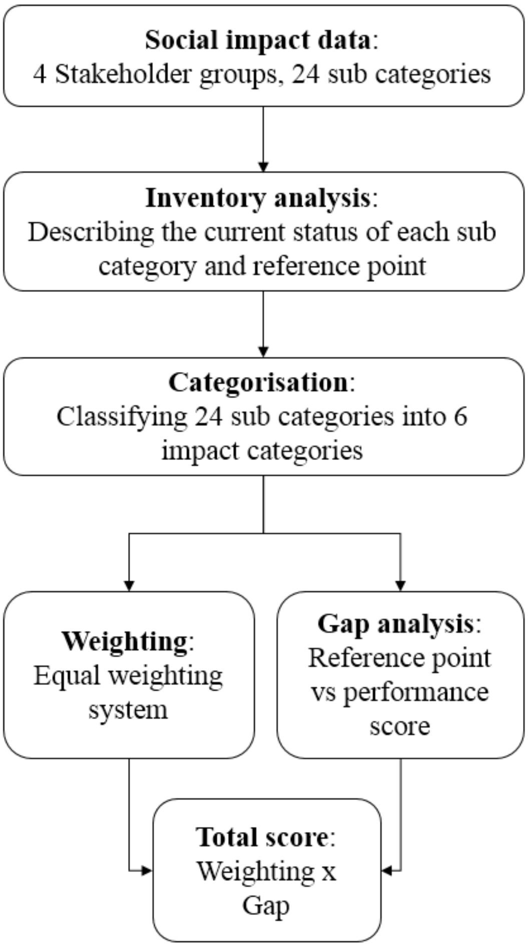


Figure 5.16 S-LCA framework applied in this study

Table 5.17 Equal weighting system applied for S-LCA

Vessel	Weight 1	Weight 2	Total weight (Weight 1 x 2)
Human rights	0.17		
Child labour		0.33	0.06
Forced labour		0.33	0.06
Equal opportunities		0.33	0.06
Working condition	0.17		
…		…	…
Health and safety	0.17		
…		…	…
Cultural heritage	0.17		
…		…	…
Socio-economic repercussions	0.17		
…		…	…
Governance	0.17		
…		…	…

5.5.2 Inventory analysis

In the S-LCA, the inventory process describes the social attributes for each subcategory based on the interview and observations conducted during the first fieldwork. Table 5.18 shows the inventory analysis for the S-LCA, whilst a complete description is provided in Appendix O. The following paragraphs will explain one example, this being subcategory freedom of association and collective bargaining, which consists of three indicators: fishers are free to undertake collective bargaining; the presence of the fishers' union; and the freedom to join the union.

The relationship between the owner and the fishers has been built based on trust, and the nature of the collaboration is a mutual need. Therefore both fishers and owners have a strong bargaining position. For example, in the PD vessel, typically, the owner decides to go or not to go fishing based on their financial situation, however, sometimes the decision is driven by the skipper on behalf of the fishers due to their financial demand. As one of the owners said:

"When they came to me asking to go fishing, what could I do? I should help them even though I did not have so much left" (Respondent O.1.0.1).

It can be seen that the owners are aware that they need the fishers, so the owners will help and support the fishers although they have their own financial problem. A further example demonstrates that fishers/skippers can negotiate their sharing percentage, even though it is not going to be significantly different to the ones that are commonly applied.

Furthermore, with respect to the local government and port authority, fishers are free to convey their aspirations which are typically represented by the fishers' unions. When this study was conducted, a group of fishers living in the border area of the fishing port were in negotiations because their housing area was to be relocated due to a fishing port development programme.

Table 5.18 Summary of inventory analysis

Main stakeholder groups	Sub categories	Inventory indicators	Inventory data
Workers (fishers/skippers, port-based workers)	Freedom of association and collective bargaining	Fishers are not conditioned by any restrictions on the right to collective bargaining.	…
		The presence of unions	…
		Fishers are free to joins union of their choosing	
	Child labour	The absence of working children under 18 years old	
	Fair salary	Income from fishing compared to minimum wage	
	Working hours	Decent working hours	
	Forced labour	Workers voluntarily agree upon the employment terms	
		Worker are free to terminate their employment within the prevailing time	
		The worker is not bonded by debts exceeding legal limits to the employer	
	Equal opportunities	Women in the labour force	
		Presence of discrimination	
	Health and safety	The frequency of occupational accidents	
		Preventing and handling measures	
	Social benefit/social security	Social benefits provided to the fishers	
Value chain actors (vendors, owners, sellers, fish buyers, second-hand goods buyers)	Fair competition	Documented statement or procedures to prevent engaging in or being complicit in the anti-competitive behaviours	
	Suppliers relationship	The strength of the relationship between the fishing vessel owners and vendors.	
Local community (fisher' wives, youth and non-fishing community)	Delocalisation and migration	Evidence of migration due to fishing activities	
	Community engagement	The diversity of community stakeholder group that engages in fishing activities	
	Cultural heritage	Presence of traditional ceremony	
	Respect for indigenous rights	The strength of policies in place to protect the rights of indigenous community members	
	Local employment	Percentage of workforce hired locally	
		Percentage of spending on local suppliers	
	Access to immaterial resources	Presence of community education initiatives	
	Access to material resources	Extraction of material resources	
	Safe and healthy living conditions	Neighbourhood environment	
	Secure living conditions	Presence of security issues related to the fishing activities	
Society (the government, influential figures)	Public commitment to sustainability issues	Presence of actions related to sustainability promotion	
	Prevention and mitigation of conflict	Level of existing conflict	
		Conflict management	
	Contribution to economic development	Contribution to the regional economy	
	Free from corruption	Presence of actions to prevent corruption	
	Development of Technology	Involvement in technology transfer programme or project	
		Partnerships in research and development	

The fishers' union, a national organisation called the National Fishers' Association (officially HNSI) has been established since 1973 with the aim of strengthening fishers' influence on the national development framework, and promoting their aspirations (Agrofarm, 2017). Its branches are distributed throughout Indonesia, including Palabuhanratu. Fishers' participation in the HNSI is voluntary. The organisation plays a significant role in the community, although it is rather more involved in politics than social actions. There are also several fishers' groups, based on the types of fishing gear. The government encourages these groups to empower the fishers. At this point, it can be said that in practice, the fishers are free to join the associations and to undertake collective bargaining.For impact assessment purpose, this inventory result requires quantification by means of reference points. Therefore, the standards, regulations and other literature that can be used as references for each subcategory were listed (see Appendix O). For example, the reference point that is used to score the freedom of association and collective bargaining is explained as follows.

Firstly, according to the Indonesian Constitution 1945, Article 28, citizens are free to associate and assemble, as well as express oral and written opinion, and this is regulated by law (Indonesian Constitution 1945). Secondly, relating to the fishers' union, MMAF regulates the system and certification of human rights in fisheries industry, which mentions that fishers have the right to form and join the association (MMAF, 2015). Thirdly, fishers are also encouraged to form a working group as part of the national empowerment programme, as stated the Guidelines for National Fisheries Empowerment (MMAF, 2013).

The characteristics of the fishing community between different types of fishing vessels are mostly homogenous. They live in the same neighbourhood with interconnected occupations, being based in the same port, conduct fishing in the same areas and have similar work patterns (one-day fishing). Likewise, although the vessels are operated differently, it is possible to work with the same vendors and the same buyers. Due the great similarity and potential for overlapping assessment, the S-LCA subcategories will be assessed as a single community. However, there are six minor differences which will be used to compare the social performance of each fishing vessel, as follows.

1. Fair salary

   As fishers in Palabuhanratu receive a shared income, the fairness of the salary can be seen from the share for both the owner and fishers as seen in Table 5.9. By considering both stakeholders, it is argued that the highest share is found in the TN vessel, followed by the HL, LF and the PD vessels.

2. Working hour

Generally, fishers do not have fixed working hours and working days, as it is highly dependent on the fish seasons, weather and sometimes the availability of operational costs. Fishers from the studied vessel typically work for more than 10 hours/day, either conducting day or night fishing. They might have a more extended trip (more than one day) occasionally. In this case, even though they go to fishing grounds further away, they will stay overnight at the nearest quay/marina and undertake a one-day trip from that place.

Amongst the studied vessels, it is argued that the most decent working hours is in the LF vessel. Even though the working hours is more than 10 hours/day, the fishers have a chance to take a rest when the gear is being operated, as the gear will be soaked for about 2-3 hours/setting and the setting can be done 3 to 4 times/trip. In the second place is the TN vessel. When operated in the active mode, the working hours is rarely reduced to be less than 10 hours/day, however, when a passive method is applied, the operational time is only 2-3 hours/day. Furthermore, Friday is the day off fishing due to religious reasons (Friday prayers). It is not a strict rule, as some fishers will keep fishing if there is a lot of fish. The next operation is the HL vessel. Being operated mostly during the night-time (from 4 pm to 6 am), the vessel is occasionally operated during the daytime. When this happen, the working hours will be reduced up to 4-6 hours due to the weather issue. The least decent working hours is found in the PD vessel. The operational time is the same as the TN vessel when conducting an active fishing operation.

3. Health and safety

Regarding the survey, 36.7% of the respondents confirmed that they had an accident while working at sea. The most common accident experienced by the fishers was suffering from a hook and getting a sprain when hauling the nets. One hand lining fisher stated that he had been burnt in 2008 when a lamp exploded. During that time he used a kerosene lamp fuelled by petrol. Another experience was capsizing which happened during rough weather. Narrowing down the result, most incident is found in the HL vessel as 71% of HL fishers confirmed that they had experienced an accident whilst working on board. It is followed by the TN and PD vessels which constitute 57% and 25% respectively. Meanwhile, no respondents from the LF vessel has had an accident at sea.

4. Community engagement

   Fishing activities in Palabuhanratu relate to different types of community members from fishing to non-fishing related backgrounds, such as boat builders, fish traders, seafood producers, fishing boat rental, a teacher in the vocational fisheries school, general traders and restaurant entrepreneurs. By number, the LF vessel engages more people than other vessels. At least 30 people are involved in the LF fishing, whilst in the PD, HL and the TN vessel are 20, 8 and 6 people respectively.

5. Access to material resources

   Each vessel has the same access to the material resources, however different fishing operations have resulted in different requirement on the fishing inputs. The calculation of fishing inputs per kg catch and £ revenue has been presented in Figure 5.8, which reveals that in general, the TN vessel use the largest inputs followed by the HL, PD and the LF vessels.

6. Contribution to the economic development

   The contribution to the regional economic was assessed based on the value of fish production landed by each vessel. As seen in Table 5.3, the LF vessel produces the highest value, followed by the PD, HL and TN vessel.

5.5.3 Impact assessment and result interpretation

In this stage, the performance of each subcategory was scored based on the references point using the five-point Likert scale, where 1 = very poor, 2= poor, 3= moderate, 4= good, 5= very good. The score was given based on the researcher's knowledge, supported by judgments from the stakeholders. The final mark for each subcategory is the average from at least three different scores. In each vessel, most subcategories will have the same mark, except six differences explained in Section 5.5.3. Those subcategories were scored using the reference point, yet some additional points was added based on the performance rank of each vessel. For example, the basis score for the fair salary is 3.75 and the fairness rank is TN, HL, LF and PD vessels. In this case the score for the TN vessel is 3.75, whilst the score for HL, LF and PD vessel is 3.50, 3.25 and 3 respectively. This method gives a proportional comparison between different impact categories and vessels.

The reference point was assumed to be the ideal condition scored with 5 points, hence, the gap can be identified. In the case where no reference point was available, stakeholders were asked to score the subcategory relatively regarding their expectations (maximum 5 points). Table 5.19 shows the weight for each subcategory, followed by its gap. Subsequently, the social impacts is presented in Figure 5.17, whilst the detail calculation is provided in Appendix P. The final score represents the gap between the current practices and the reference points hence the lower is the better. This result has been validated by the stakeholders during the FGD.

As seen in the figure, the lowest gap is found in the LF vessel, followed by the TN, PD and the HL vessel. This result suggests that the LF vessel is the safest, most productive and most labour intensive compared to other studied operations. In each vessel, both human rights and governance categories have the same gap, whilst the different gaps are shown in the remaining impact categories.

Table 5.19 Gap analysis and the weighting factor

Impact categories	Subcategories	Weight	Gap			
			PD	TN	HL	LF
Human right	Child labour	0.06	3.50	3.50	3.50	3.50
	Forced Labour	0.06	1.42	1.42	1.42	1.42
	Equal opportunity	0.06	1.00	1.00	1.00	1.00
Working condition	Freedom of association and collective bargaining	0.06	0.42	0.42	0.42	0.42
	Fair salary	0.06	4.50	3.75	4.25	4.00
	Working hours	0.06	1.00	0.50	0.75	0.25
Health and safety	Health and safety	0.08	2.38	2.50	2.63	2.25
	Social benefit/social security	0.08	1.25	1.25	1.25	1.25
Cultural heritage	Delocalisation and migration	0.03	0.00	0.00	0.00	0.00
	Community engagement	0.03	0.50	1.00	0.75	0.25
	Cultural heritage	0.03	0.00	0.00	0.00	0.00
	Respect of indigenous rights	0.03	0.25	0.25	0.25	0.25
	Access to immaterial resources	0.03	0.75	0.75	0.75	0.75
	Access to material resources	0.03	0.75	1.25	1.00	0.75
Socio-economic repercussion	Safe and healthy living condition	0.03	2.50	2.50	2.50	2.50
	Secure living condition	0.03	0.75	0.75	0.75	0.75
	Local Employment	0.03	0.00	0.00	0.00	0.00
	Prevention and mitigation of conflict	0.03	0.89	0.89	0.89	0.89
	Contribution to economic development	0.03	0.25	0.75	0.50	0.00
	Suppliers relationship	0.03	0.50	0.50	0.50	0.50
Governance	Public commitment to sustainability issues	0.04	1.00	1.00	1.00	1.00
	Technology development	0.04	0.44	0.44	0.44	0.44
	Free from corruption	0.04	0.67	0.67	0.67	0.67
	Fair competition	0.04	1.50	1.50	1.50	1.50

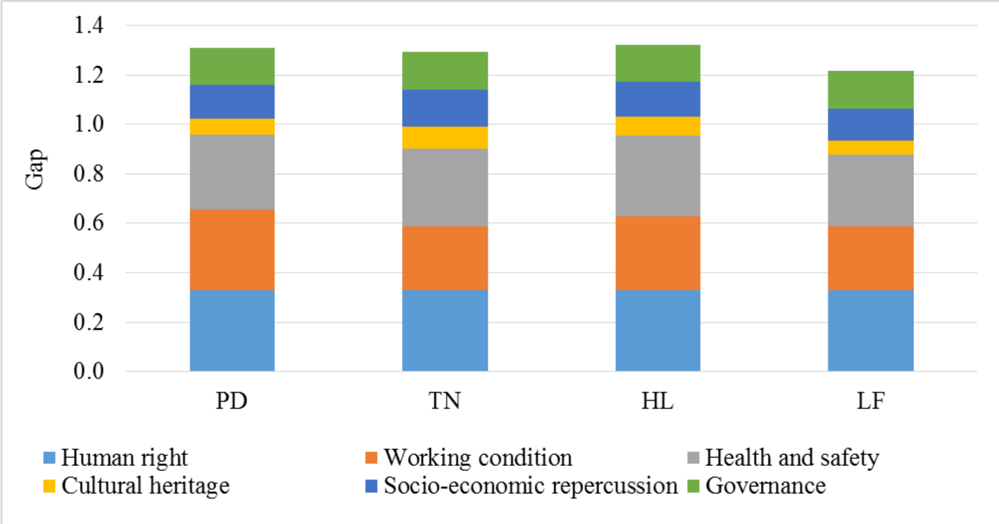


Figure 5.17 S-LCA result of studied vessels presented in gap between the current practices and the reference points

Furthermore, Figure 5.17 reveals that a large gap is shown in human rights, health and safety, and working conditions indicating that those three categories are the most critical issues in the fishing community, which requires further improvement. Furthermore, the workers are the stakeholders who are most affected. In contrast, the narrow gap found in cultural heritage confirms that the fishing activity in Palabuhanratu has been conducted and appropriately managed in line with the principal to protect it. The following paragraphs will explain the issue in each impact category.

1. Human rights

The primary issue in human rights is derived from the presence of child labour. Most fishers admitted that they officially became a fisher shortly after finishing junior high school (Year 9) or even elementary school (Year 6). The distribution of educational background reveals that 77% of fisher respondents have completed elementary school. Furthermore, when this survey was conducted, some of the fishers and port-based workers were classified by law as children (under 18 years old).

2. Working conditions

The large gap in the working conditions category is essentially caused by salary fairness. Small-scale fisheries are usually associated with poverty due to low share. Furthermore, even though they earn a significant amount of money during the peak season, their incomes will decrease significantly during the low season. Additionally, they might individually be saddled with continuous debt as part of their financial survival strategy.

3. Health and safety

Workers groups also deal with safety and social benefit issues. Regarding safety, no standard safety equipment and first aid kits are provided on any of the studied vessels. This is prevalent in traditional fishing vessels. In an emergency situation, the fishers will rely on their swimming skills. The fact that most of them are experienced fishers might drive this behaviour. Fortunately, the occupational accident rate which could be a serious issue is insubstantial, as confirmed by more than 90% of the respondents. A typical incident onboard is an accident which causes a minor injury, such as a cut or sprain. Although it is undeniable that generally, fishers feel safe while working onboard, in compliance with the national regulations, safety equipment and first aid kits should be provided.

4. Cultural heritage

No significant issue is established regarding cultural heritage. It is plausible as SSFV operations are run by local people, who are undeniably upholding local wisdom. The firm belief in the community that the waters are a blessing has driven the ceremonial offering which is undertaken on the 6th of April each year. The ceremony is considered not only as a community fishing event but also an iconic ceremony, which is supported by the diverse local community. Due to its significance and popularity, the 6th of April has been acknowledged as national fishermen's day. Additionally, 2017 was the 57th national celebration.

5. Socio-economic repercussions

The fisheries sector, together with agriculture and forestry, are still considered as the dominant economic sectors in the region, which contributed in the region of 23% to the regional gross domestic product in 2013 (Centre for Statistics of Sukabumi Regency, 2016). Furthermore, according to The Government of Palabuhanratu District (2016), the percentage of households which relates to the marine fisheries sector was approximately 65%. The existence of the marine fisheries sector in supporting regional economic development was strengthened by the opening of the fishing port in 1991, however, productivity in this sector remains low. It is confirmed by the regional statistics report in 2015, which revealed that approximately 37% of residents are living in poverty and most of them are fishers (Centre for Statistics of Sukabumi Regency, 2016).

The primary issue relating to socio-economic impacts on the community is poor housing and home conditions, which is associated with poverty. The fishers live in two types of neighbourhood, specifically, fisher and mixed neighbourhood. The fisher neighbourhood is a semi-permanent residential area built by the fishers, which is situated next to the fishing port. The area was built on an empty field owned by a national oil company. The fishers live in small houses, roughly 21-36 m^2, with poor sanitation, inadequate access to clean water and limited toilet access. The mixed neighbourhood, in contrast, is the place where fishers live with diverse community members in the permanent residential area around the town centre or in the nearest villages. This neighbourhood has a better environment than the fisher’s village.

6. Governance

The government provides regulations which controls the utilisation of marine resources and educates the fishing community to participate in protecting the marine environment. As a result, the fishing community is aware of destructive fishing impacts and is vehemently against damaging the environment. However, regarding the protection of certain species, more efforts are still required to educate fishers, as there are still a variety illegal fishing practices. Society encourages the fishing community to be cooperative in technical development programmes in both fishing operations and fishing port-related projects. This is because they are aware that community participation is essential to achieve the main goal of economic prosperity successfully.

The performance of the governance aspect in fisheries activity is generally satisfactory. The most substantial gap is found in fair competition, which is primarily caused by the fact that there is insufficient mechanism to prevent anti-competitive behaviour.

In contrast to S-LCA result in small-scale fishing operations, a study in the palm oil industry in Indonesia (Manik *et al.*, 2013), showed that the largest social gaps were found in cultural heritage, followed by working conditions and governance aspects. The issue associated with cultural heritage is deforestation, which undermine the local community’s livelihood. In Palabuhanratu, conversely, the small-scale fishing business is run by local people, so the cultural heritage aspect is virtually unaffected. Regarding working conditions, the significant problems in the palm oil industry are related to low paid job opportunities, job security and insufficient legal protection, which is generally the same as the studied fishing practices. Lastly, regarding governance, stakeholders from both the palm oil industry and fishing operations agreed that the business is not entirely free of corruption.

5.6 Sustainability assessment

Following the impact assessment, the next task is conducting the SA. No standard measurement is available to define whether a fishing vessel operation is sustainable. Therefore, in this study, the sustainability performance of each studied vessel is measured against the other by comparing the environmental, economic and social impacts of the fishing operation. Different types of analysis performed in Section 5.3, 5.4, and 5.5 produce various results which represent the impact of fishing operations. Amongst the tools of analysis, life cycle analysis is considered as the most comprehensive tool and it is applied in all three sections. Therefore, in order to provide proportional assessment, sustainability performance was calculated by aggregating LCA, LCC and S-LCA results. Focusing on the life cycle analysis avoids double counting as some analysis is actually overlapping. However, it does not mean that other tools are not important because those results are complete to each other.

5.6.1 Methodology

LCA, LCC and S-LCA results are presented in different measurement units. In order to aggregate the values, the results were normalised using the ranking method and weighted using an equal weighting system, as illustrated in Figure 5.18. In the ranking process, the impacts derived from each vessel were ordered from the best (1st place) to the worst (4th place). Next, the rank was reversed to define its score, where score 4 is for 1st place and score 1 is for 4th place. Subsequently, each indicator in the same level was weighted equally, as seen in Table 5.20. This means the same weighting factor is applied for indicators under the LCA (human health, ecosystem quality, climate change and resource use), and another equal weighting is applied for two indicators under human health (DAYL/kg and DAYL/£). Total weight for each indicator is obtained by multiplying the weight in each level. Finally, sustainability performance was scored by multiplying the point of each indicator with its weight.

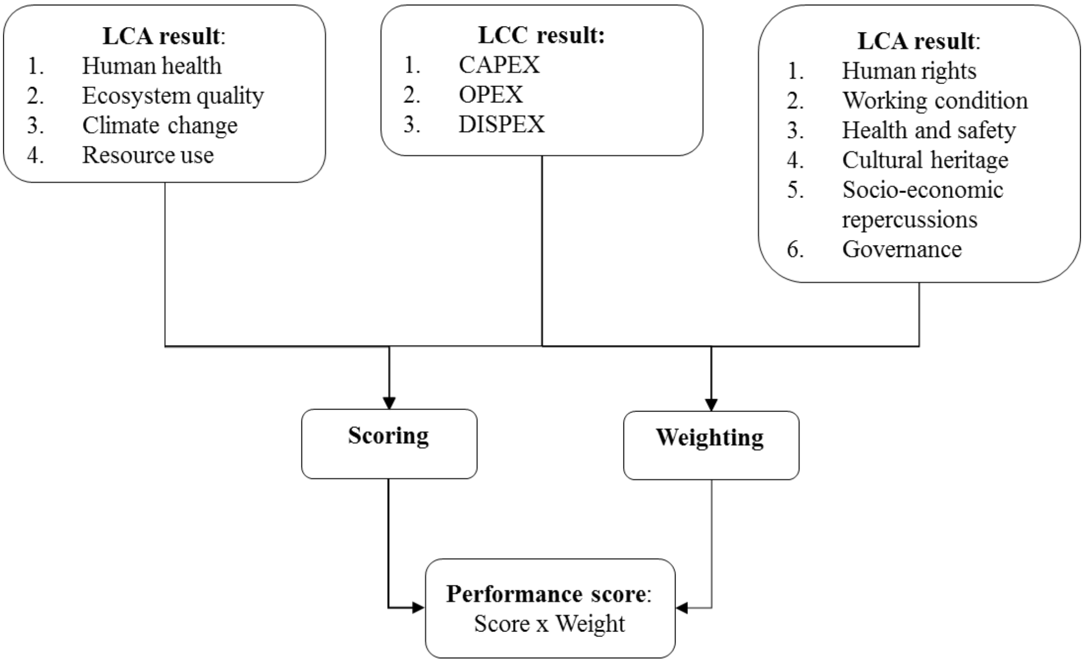


Figure 5.18 Sustainability assessment method

Table 5.20 Equal weighting system applied for sustainability assessment

Vessel	**Weight**			**Total weight**
	W1	**W2**	**W3**	**W1xW2xW3**
LCA	0.33			
Human health		0.25		
DAYL/kg			0.50	0.042
DAYL/£			0.50	0.042
Ecosystem quality		0.25		
…			…	…
Climate change		0.25		
…			…	…
Resource use		0.25		
…			…	…
LCC	0.33			
…		…	…	…
SLCA	0.33			
…		…	…	…

5.6.2 Result

Table 5.21 shows the weighting factor for each sustainability indicator and the score for each vessel. According to the table, the total score for sustainability performance is presented in Figure 5.19. Unlike the impact assessment, the scores here refer to the quality of sustainability, hence the higher is the better. Based on the assessment framework applied in this study, it can be seen that the best sustainability performance is shown by the LF vessel, which leads the chart in all indicators. On the other hand, the lowest performance is found in the TN vessel. The environmental performance of the studied vessels is higher than the economic performance, except in the TN vessel. Furthermore, the social performance is higher than other indicators, except for the HL vessel. This suggests that environmental and social aspects are important issue in the TN and HL vessels respectively.

Examining the main characteristics of fishing vessel operations, generally, it can be concluded that the environmental performance of passive fishing are better than active fishing, whilst in economic and social aspects no strong evidence is found to support the conclusion. Furthermore, the social performance of the pelagic fishing is higher than the

Table 5.21 Weighting and scoring for sustainability assessment

Categories	Indicators			Weight	Score			
					PD vessel	TL vessel	HL vessel	LF vessel
Environmental performance	LCA	Human health	DALY/kg	0.420	3	1	2	4
			DALY/£		3	1	2	4
		Ecosystem quality	PDF*m2*yr/kg		3	1	2	4
			PDF*m2*yr/£		2	1	4	3
		Climate change	kg CO_2 eq/kg		3	1	2	4
			kg CO_2 eq/£		1	2	4	3
		Resources	kJ primary/kg		3	1	2	4
			kJ primary/£		2	1	4	3
Economic performance	LCC	CAPEX	Cost/kg	0.560	4	1	2	3
			Cost/£		4	2	3	1
		OPEX	Cost/kg		3	1	2	4
			Cost/£		1	2	3	4
		DISPEX	Cost/kg		1	4	2	3
			Cost/£		1	3	2	4
Social performance	S-LCA		Human rights	0.560	3	3	3	3
			Working conditions		2	4	3	4
			Health and safety		3	2	1	4
			Cultural change		4	1	2	3
			Socio-economic repercussions		3	1	2	4
			Government		4	4	4	4

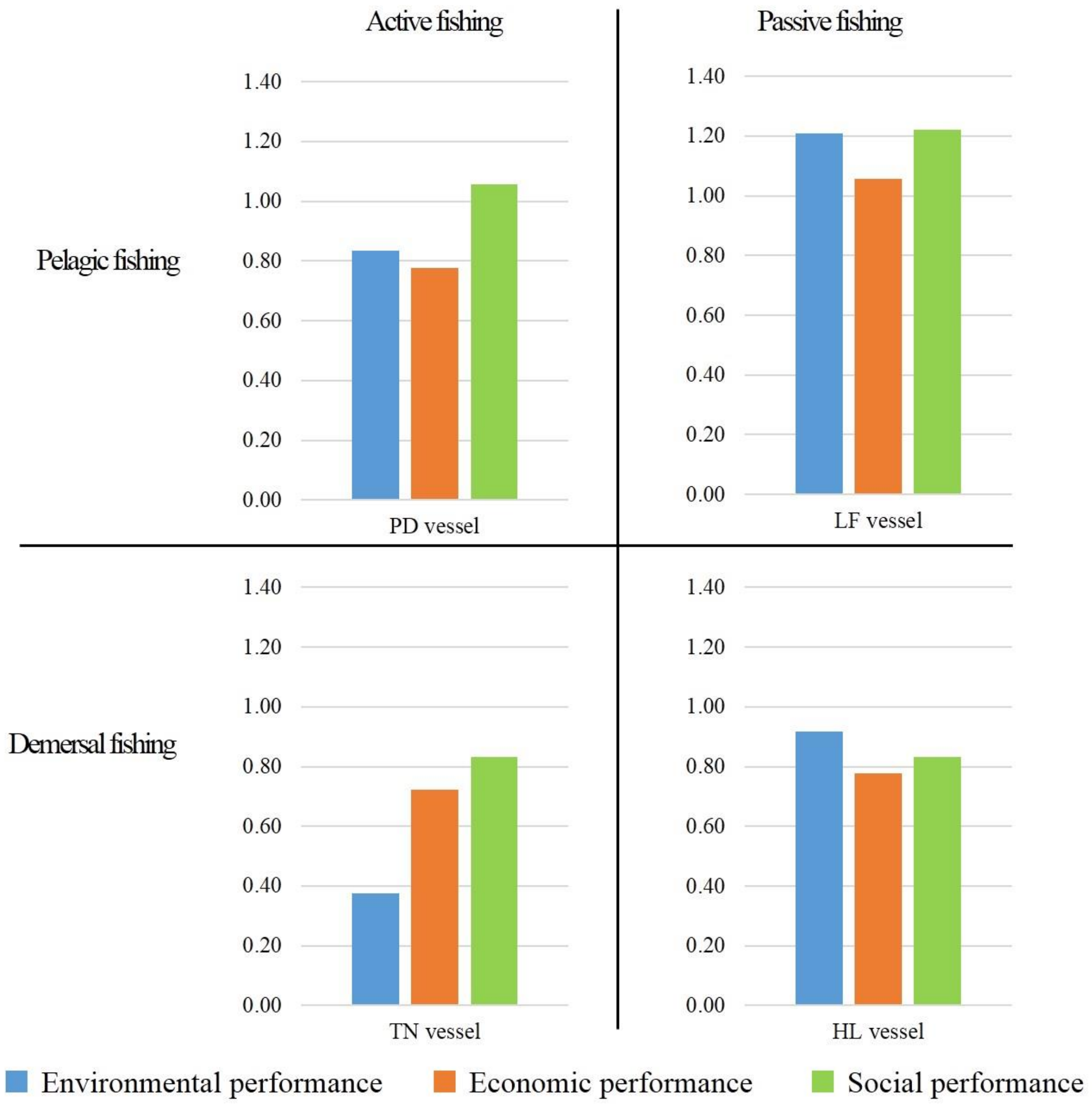


Figure 5.19 Sustainability performance of the studied vessels

demersal fishing, however the comparison showed in Figure 5.19 cannot be used to justify that pelagic fishing is more sustainable than demersal fishing, since each vessel show inconsistent results in terms of environmental and economic aspects. This result suggests that formulation of improvement measures should really depend on the management goal, as emphasising different focuses will produce different actions. For example, the national report showed that an opportunity to exploit the fish resources in the demersal fish and the crustacean group is wide open due to the sustainable stock (MMAF, 2017b). Accordingly, the development of passive demersal fishing could be the best option available, as the active demersal fishing is less sustainable in terms of environmental aspects.

Benchmarking will show the sustainability level of the studied fishery relative to other fisheries. However, sustainability performance is very specific assessment, which providing an equal comparison to other fishing practices is very challenging. Alternatively, the performance of each indicator resulted from this research was individually compared to other fisheries, and the discussion is presented in the next chapter.

5.7 Summary

The sustainability of the fishing vessel operation has been assessed in the environment, economic and social aspects, with specific analysis studies. In general, the assessment is limited to the activities from the acquisition of fishing attributes (equipment to support the operations), fish catching process, fish selling process and the end of life of each attribute. Stakeholders involved in those activities were included in the assessment. Two functional units were used in this study, specifically, one kg catch and one pound of revenue.

Environmental impacts were analysed using three tools, i.e. fuel consumption, CO_2 emissions and LCA. Fuel use analysis shows that to land a one kg catch, the TN and HL vessels consume more fuel than the PD and LF vessels. In terms of earning £1 of revenue, all vessels show similar responses except the HL vessel where its consumption is 44% lower than the counterparts. In addition, when the percentage of energy yield is considered, the highest and the lowest ep-EROI are found in the LF vessel with 25% and the TN vessel with 4%. CO_2 emissions was analysed using emissions factors published by the Indonesian government. Thus, the result of the analysis shows the same configuration as the fuel consumption analysis.

In the LCA analysis, environmental impacts are assessed in four categories, i.e. human health, ecosystem quality, climate change and resources use. In all vessels, impact on human health and resources use are responsible for the most significant percentage. In total, both impacts might reach between 84-90% and are primarily derived from fuel consumption whose inputs ranges from 43-83%. As fuel is the major contributor, the result shows the same response as fuel consumption analysis, where the TN and HL vessels generate more impacts to land a one kg catch than other vessels. Furthermore, the

LCA analysis reveals that the LF vessel has the least impact in terms of catch quantity and value.

Economic impacts were assessed using profit analysis, LCC and financial analysis. The result from the profit analysis indicates that the owner receives the highest share, between 18% and 39% of the total revenue, whilst the fishers share in the range of 3-21%, depending on the vessel types. According to the LCC result, the largest cost component in all vessels is the personnel and operational cost, ranging from 32-41% and 28-41% respectively. In line with the LCA result, the LF vessel demonstrates the best performance in the LCC for both functional units. However, regarding financial analysis, the best performance is found in the PD and HL vessels, as it has a higher IRR and faster PP than the LF vessel. In both environmental and economic assessment, the TN vessel is constantly ranked in last place.

The social impact assessment was conducted using the S-LCA approach. As the characteristics of the fishing community between the different operations is generally the same, the assessment was carried out on a single community basis by considering six differences including fair salary; working hour; health and safety; community engagement, access to material resources, and contribution to the economic development. The assessment involved four stakeholder groups (workers, value chain actors, local community and society) and investigated 6 impact categories (human rights, working conditions, health and safety, cultural heritage, socio-economic repercussions and governance). The result shows that the LF vessel is the safest, most productive and most labour intensive operation. In all vessels, the significant socio-economic issues in the small-scale fishing vessel operations are human rights, working conditions, and health and safety, whilst the most affected stakeholder is the workers.

Following the three assessments, sustainability performance was assessed by comparing the environmental, economic, and social impacts based on the LCA, LCC and S-LCA results. The comparative study of different impact assessments concludes that fishing associated with the LF vessel is the most sustainable operation, whilst the TN vessel is the least. In general, no strong evidence is found to conclude that passive fishing is more sustainable than active fishing. Similarly, the sustainability performance of pelagic fishing is not necessarily better than demersal fishing. This result suggests that the decision regarding improvement should really depend on the management goal.

In the next chapter, the assessment results are subsequently used to identify the areas for potential improvement and to formulate the implementation strategies. In addition, further comparison with results from other studies is also presented in order to provide general insight into the level of sustainability performance of the studied vessels.

Chapter 6. Formulation of possible measures, best practice and implementation strategies

6.1 Introduction

In Chapter 5, the sustainability assessments of the existing operations have been described and the next task is improving the current performance in order to promote sustainable fishing vessel operations. Therefore, this chapter will describe how the possible measures and best practice are developed using the previous information. Besides, the strategies to implement best practice are also formulated by considering different types of stakeholder. According to the research design described in Figure 1.3, this chapter will answer the second research question. The principal discussion will focus on four aspects, namely areas for potential improvement, possible measures, best practice and the implementation strategies whose general process is explained below.

6.2 Methodology

In order to identify targets for potential improvement, the discussion is focused on the impact assessment result, specifically, areas with the most significant adverse impacts. Subsequently, possible measures were developed by targeting a reduction of the negative impact. Different types of literature were used to support the formulation process.

Given that a fishing operation is also associated with fisheries management that is the government's authority, the possible measures are expressed in two categories, practical and policy levels. At the practical level, the measures are formulated based on the perspectives of workers, value chain actors and the local community, whilst at the policy level, the measures are associated with the government's actions. The government referred to in this study is limited to the institutions that are responsible for fisheries development in Palabuhanratu including:

1. PPN Palabuhanratu, which is responsible for activities around fishing port and the surrounding waters.

2. The fisheries council is representing local government, which is the policy maker at the regional level. The authority is not only limited to the Palabuhanratu area but also surrounding areas registered with the same regency.
3. MMAF, which is the policy maker at the national level. Administratively, PPN Palabuhanratu is under the MMAF's management.

In order to evaluate the effectiveness of the possible measures, different scenarios are simulated using the fishing operation and life cycle based models, which have been developed in Chapters 4 and 5. In addition, a trade-off between the advantages and disadvantages of the possible measures are also discussed to appraise its suitability as a proposed measure.

It is worth noting that not every proposed measure is achievable. Hence, further analysis is performed to identify the most practical measures for the studied system, referred to as best practice**.** Accordingly, the proposed measures were discussed with the stakeholders by means of FGDs, which allow stakeholders to discuss the each measure and justify its applicability. FGDs were conducted during the 2nd fieldwork by inviting 79 respondents, as detailed in Table 1.1. Those people are not necessarily the same as the ones who participated in the 1st fieldwork.

Regarding the recommendations for the policy level, the solutions were discussed with the government representatives from the aforementioned institutions. This mechanism gives an idea of how the development of sustainable fishing vessel operations should be implemented in the existing operations in order to achieve the optimum improvement result. Figure 6.1 reveals the flowchart relating to the formulation of best practice and implementation strategies.

Table 6.1 FGD activities during the 2nd fieldwork

Activities	Stakeholder group	Number of participants
FGD 1	Fishers/Skippers	9
FGD 2	Fishers/Skippers	8
FGD 3	Fishers/Skippers	8
FGD 4	Owners	10
FGD 5	Owners	9
FGD 6	Sellers	8
FGD 7	Other value chain actors	7
FGD 8	Housewives	8
FGD 9	Youth	7
FGD 10	Non-fishing related jobs	5

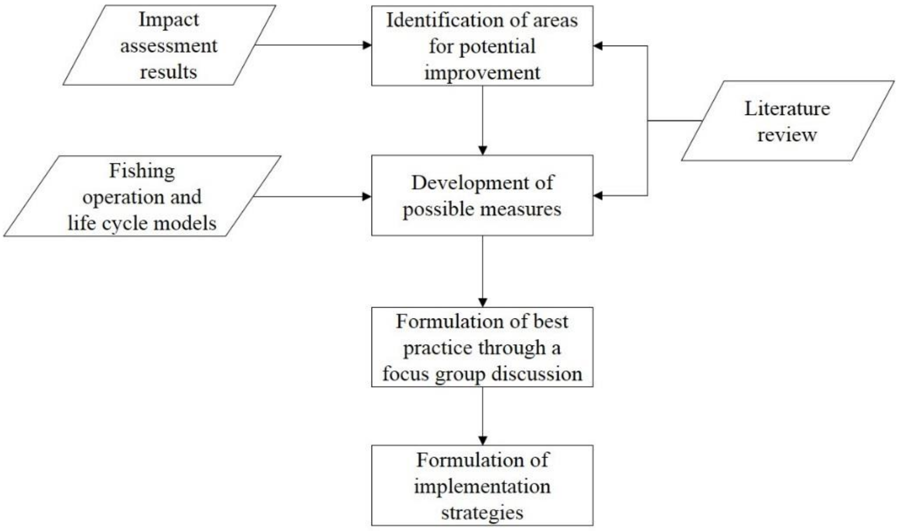


Figure 6.1 Flowchart to develop possible measures for improving sustainability and formulate the implementation strategies

6.3 Identification of areas for potential improvement based on the impact assessment result

This section discusses the assessment results presented in Chapter 5 in order to identify the areas for potential improvement. Not every area is significant in all vessel, hence the discussion includes the relevance of environmental and economic impacts to each studied vessel, which is summarised in Table 6.2 and 6.3 respectively.

Table 6.2 Relevance of potential improvement to each vessel in relation to environmental performance

Indicator	Area for potential improvement	Relevance			
		PD vessel	TN vessel	HL vessel	LF vessel
Energy consumption	Fuel consumption	√	√	√	
	Catch per trip	√	√	√	
	Fish price	√	√	√	√
CO_2 emissions	Fuel consumption	√	√	√	
	Catch per trip	√	√	√	
	Fish price	√	√	√	√
	Fuel type	√	√	√	√
LCA	Fuel consumption	√	√	√	√
	Catch per trip	√	√	√	√
	Fish price	√	√	√	√
	Ice consumption	√	√	√	
	Lubricant consumption	√		√	√
	Electricity consumption	√	√		√
	Hull maintenance	√	√		√
	Paint use	√	√		√
	Cool box material		√	√	
	Plastic drums				√
	Wood use	√	√		

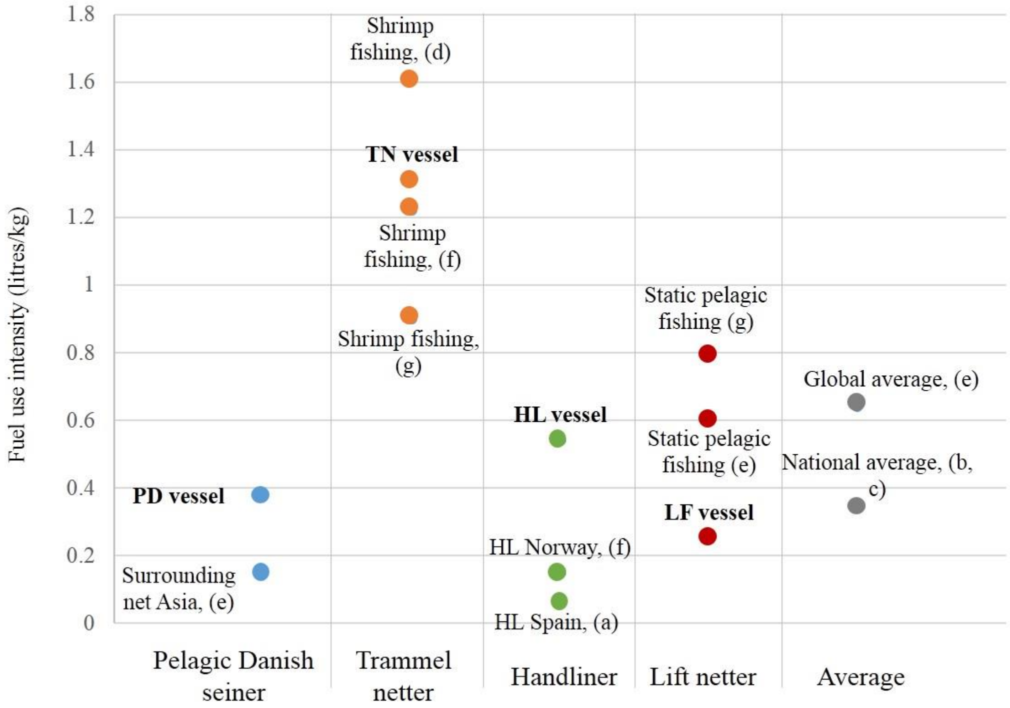
Table 6.3 Areas for potential improvement related to economic performances

Indicator	Area for potential improvement	Relevance			
		PD vessel	TN vessel	HL vessel	LF vessel
Fisher's profit	Fuel consumption		√	√	√
	Catch per trip	√	√	√	√
	Fish price	√	√	√	√
	Sharing system	√	√	√	√
	Fuel price		√	√	√
	Number of fishers	√	√	√	√
Owner's profit	Fuel consumption	√	√	√	√
	Catch per trip	√	√	√	√
	Fish price	√	√	√	√
	Sharing system	√	√	√	√
	Fuel price	√	√	√	√
	Number of fishers			√	
	Number of gear				√
LCC	Fuel consumption	√	√	√	√
	Catch per trip	√	√	√	√
	Fish price	√	√	√	√
	Sharing system	√	√	√	√
	Fuel price	√	√	√	√
Financial analysis	Fuel consumption	√	√	√	√
	Catch per trip	√	√	√	√
	Fish price	√			√
	Number of successful trips	√	√		
	Sharing system	√	√		√
	Fuel price	√	√		
	Number of gear				√
	Maintenance cost		√		

6.3.1 Energy consumption

This section compares FUI_{kg}, $\text{FUI}_{£}$ and ep-EROI of the studied vessels with other findings. Figure 6.2 reveals that the FUI_{kg} of the LF vessel is the only operation under the national average, which indicates that the vessel performs better than the typical fishing operations in Indonesia. However, when the value is compared to the global average, the result points out the remarkable energy consumption in the TN fishing.

FUI_{kg} from other studies were obtained from similar fishing methods using different technology, fishing capacity, and fishing grounds. Despite unequal comparison, Figure 6.2 depicts the level of energy efficiency of the TN vessel in the domain of comparable fishing operations. However, the fact that the studied vessel is conducted in more traditional ways, suggest that energy consumption in the TN vessel is an issue.



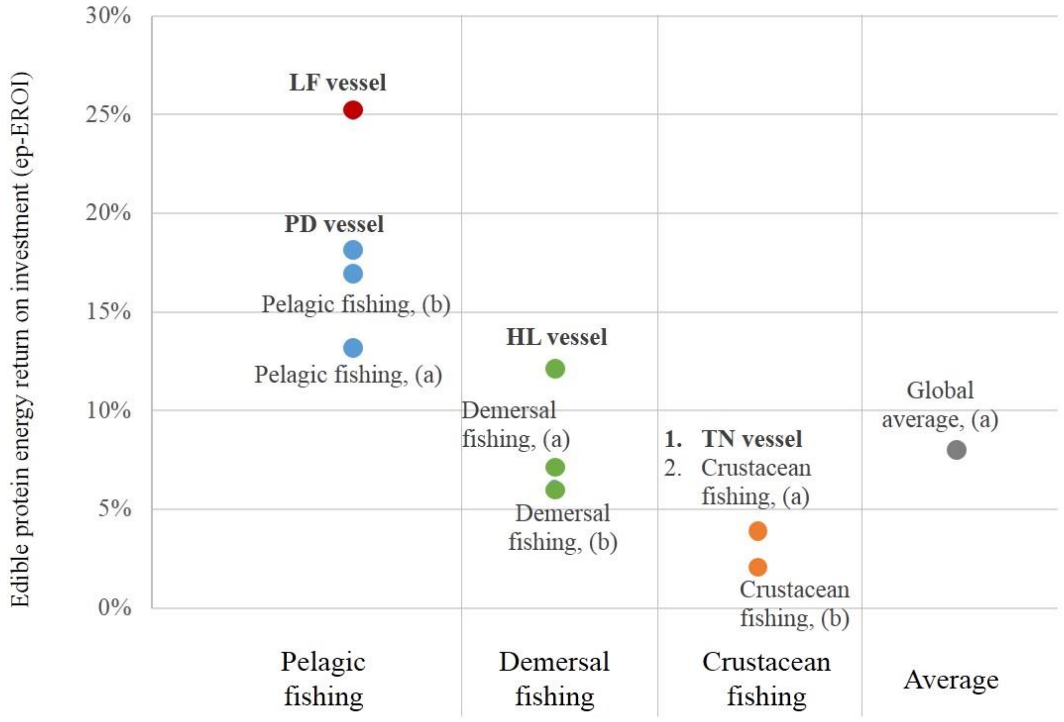
Note : the same colour indicate the fishing practice with comparable result
Sources : a. (Basurko *et al.*, 2013); b. (DGCF, 2015); c. (Pertamina, 2016); d. (Parker *et al.*, 2015); e. (Parker and Tyedmers, 2015); f. (Schau *et al.*, 2009); g. (Tyedmers, 2004)

Figure 6.2 Comparison of FUI_{kg} in different fishing practice

Furthermore, another inefficiency issue was found in the PD and HL vessels, as both vessels consume more fuel than national average and other similar fishing. In order to improve the FUI_{kg} of those three vessels, concern should focus on the fuel consumption and catch per trip.

Regarding the $FUI_{£}$, to produce £1 of revenue, the amount of fuel consumed by the PD, TN, HL and LF vessels is 0.69, 0.65, 0.36, and 0.64 litres/£ respectively (see Figure 5.3). Compared to the national average, which constituted 0.34 litres/£, all vessel spent more fuel than the typical fishing operations in Indonesia. Hence, it is argued that $FUI_{£}$ require further improvement, and therefore another concern should focus on the fish price.

As a potential protein source, the ep-EROI is an important indicator to describe energy efficiency in protein yielding. Figure 6.3 compares the ep-EROI obtained from this study and other studies. The figure confirms that the energy efficiency of the studied vessels is at the same level as the global average and, even higher for pelagic and demersal fishing. Therefore, it can be said that energy consumption in relation to yielding protein is not a substantial issue.



Note : the same colour indicate the fishing practice with comparable result
Sources : a. (Tyedmers, 2004); b. (Vázquez-Rowe *et al.*, 2014)

Figure 6.3 Comparison of ep-EROI in different fishing practice

To sum up, FUI_{kg} and $FUI_{£}$ are crucial issues in the energy consumption and in order to improve the energy efficiency, concerns should be given on fuel consumption, catch per trip and fish price.

6.3.2 CO_2 emissions

According to global fuel consumption in the fisheries sector, the amount of CO_2 emitted from the fishing activities is roughly 1.7 kg CO_2/kg catch (Tyedmers, 2005; Parker and Tyedmers, 2015). Meanwhile, in Indonesia, consumption of 2.2 billion litres of fuel to land 6.5 million tons of fish in 2014 emitted 1.1 kg CO_2/kg catch (DGCF, 2015; Pertamina, 2016). In line with FUI_{kg}, CO_2 emissions from the TN and HL vessels continuously exceed the national average, being responsible for 3.53 and 1.29 kg CO_2/kg catch respectively.

The amount of CO_2 per kg and £ of revenue from the studied vessels correspond with the FUI_{kg} and $FUI_{£}$. Accordingly, concern is given to the same aspects, which are fuel consumption, catch per trip and fish price. The pollutant is also affected by the fuel type. Therefore, another possible improvement to enhance environmental performance can focus on the implementation of a different type of fuel, which has a low carbon content, such as LPG, and this concern is associated with all studied vessel.

6.3.3 Life cycle assessment

The most significant impact throughout the life cycle of each fishing vessel is derived from supplies, vessel maintenance, vessel production, fishing gear and fish container. Firstly, the impacts generated from supplies incorporating fuel, ice, and lubricant in all studied vessels range from 86% to 97% of the total impact and it confirms that the operational stage is the major contributor throughout the vessel's lifetime. This large percentage is mainly due to the substantial amount of fishing inputs, as seen in Figure 6.4. Furthermore, even though the percentage of supplies in the LF vessel is lower than other vessels, it produces a comparable impact. These facts suggest that the potential solution to minimising the environmental impact is related to reducing the supplies.

Secondly, major impacts are resulted from the maintenance of the vessel, especially in the PD, TN and LF vessels. In the HL vessel, impact from maintenance is meagre because the vessel is a fibreglass boat which is known for a low maintenance boat.

As seen in Figure 6.5, significant impacts in the maintenance stage is driven by repainting and re-planking activities. In regard to the repainting work, concern is given to the painting materials due to the chemical substances included. The growth of marine fouling is detrimental because it damages the hull besides increasing the drag and fuel consumption. Consequently, repainting work is required every 3 or 4 months in order to clean the hull of fouling and to apply new protective layers, especially to the underwater area. As a result, repainting frequency is another aspect influencing the environmental performance. However, it should be noted that changing the repainting mechanism is a crucial decision as it requires further consideration to optimise the amount of material, types of material and the period of maintenance.

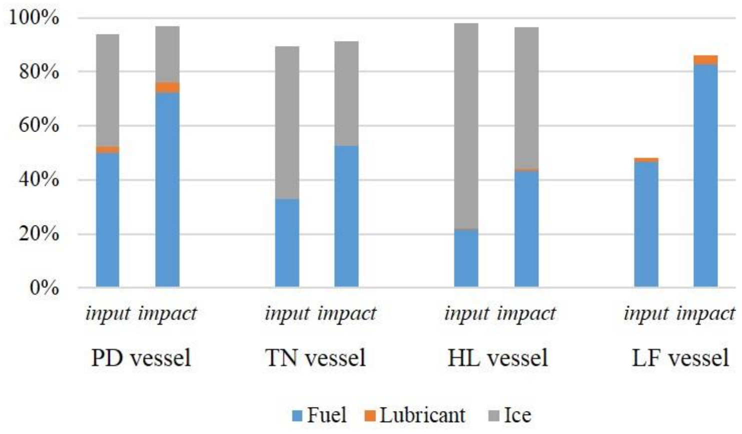


Figure 6.4 Comparison between the percentage of supplies inputs and their impacts in the studied vessels

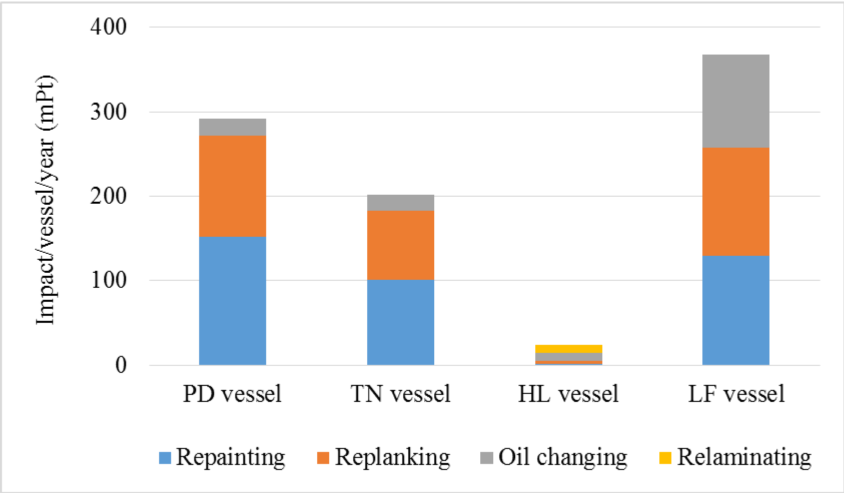


Figure 6.5 Impact contributor to the fishing vessel maintenance (per vessel/year)

Regarding re-planking, the main issue is with regards to electricity consumption. Seeing as the background process for electricity used in the assessment is specifically for Indonesia, the data is relevant to the case study. Hence, minimising the electricity consumption will elevate the sustainability performance in the context of the Indonesian fisheries.

Thirdly, regarding the production of the vessels, Figure 6.6 shows that in the wooden vessels, electricity generates a comparable impact to the wood. On the other hand, in the HL vessel, the impact of fibreglass significantly exceeds the impact of electricity. Given that wooden vessels have substantial environmental burdens suggest that improvement plan should focus on electricity consumption and wood substitution.

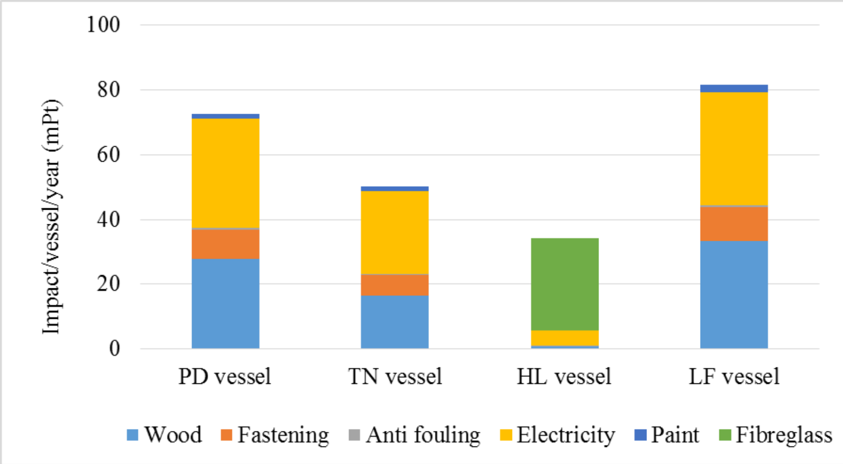


Figure 6.6 Impact contributor to the fishing vessel production (per vessel/year)

The LF vessel is also a wooden vessel, which has the similar impacts to the PD and TN vessels. However, the addition of 10 fishing gear in the form of LF platforms has resulted in a significant impact which is essentially caused by the use of plastic drums as the platform base. Therefore, plastic drums are also a possible area where the environmental performance of the LF vessel can be improved.

The further top five contributors regarding impacts are the fish containers which are found in the TN and HL vessels. The type of fish container used in both vessels is an expanded polystyrene (EPS) cool box, which is replaced on a monthly basis. Therefore, in order to improve environmental performance, the development should focus on the cool boxes material.

6.3.4 Profit

Figure 6.7 shows the comparison of the annual profit received by each stakeholder to the minimum regional salary in 2015, which is set at £1,406 per year (Governor's Decree, 2014). It can be seen that the fishers' and skippers' income is considered to be low, and this suggests that further improvement is required in all vessels. Furthermore, the figure reveals that the smaller share does not necessarily indicate less income, since it is extremely dependent on the fish production and fish price in each operation.

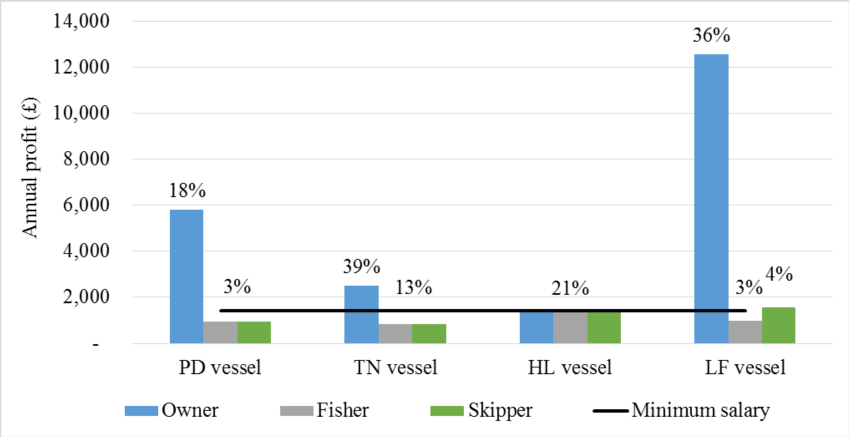


Figure 6.7 Comparison of the annual profit to minimum salary

In terms of owner's profit, the economic performance of fishing vessel operations can be presented in annual net profit (ANP) and ROI (Tietze *et al.*, 2005). The ANP is calculated by considering the maintenance and capital costs (the depreciation cost of the fishing item and annual interest). Meanwhile, the ROI is the ratio of the net profit and the total investment. Table 6.4 shows the ANP and ROI of the studied vessels compared some small-scale fishing vessels (SSFVs) around the world. The table establishes that the profit gained in the studied vessels is similar to some of the small-scale operations, especially in India. According to Tietze *et al.* (2005), ROI that is higher than 10% is considered a good result. Thus, it can be said that economically, the studied vessels and most of the other typical operations perform well.

A good performance does not necessarily mean that the owner's profit is not a crucial issue. It is because the owner should maintain the net cash flow at its healthiest level in order to sustain the fishing business for a long term period. This fact suggests that the owner's profit in all vessels should be maintained, regardless its good performance.

In order to improve both fisher's and owner's profit, concerns should be made in fuel consumption, catch per trip, fuel price, fish price, sharing system, the number of fishers and the number of the gear. The following paragraphs justify the importance of each area for improving the profit in the four studied vessels, which is summarised in Table 6.4. The table also shows the relevance of areas regarding other economic indicators to each studied vessel.

Table 6.4 Economic performance of small-scale fishing vessels globally

Area	Fishing vessels	ANP (£)	ROI
Europe	Germany, coastal cutter 10-15 m	20,979	9%
	Germany, shrimper 15-20 m	102,384	14%
	France, handliner 8-10 m	12,636	26%
	France, gillnetter 10-12 m	6,966	8%
	France, coastal trawler 15-18 m	7,452	2%
	Norway, gillnet handline 10 m	6,318	31%
	Norway, gillnet handline 15 m	11,583	12%
	Norway, line north Norway 10 m	4,374	18%
	Norway, line north Norway 15 m	18,225	38%
	Norway, coastal south Norway 10 m	1,944	6%
	Norway, coastal south Norway 15 m	12,393	8%
	Norway, coastal purse seiner 25 m	97,362	10%
	Norway, shrimp trawler 10 m	2,106	5%
	Norway, shrimp trawler 15 m	-7,533	n/a
Africa	Senegal, gillnetter 15 m	-648	n/a
	Senegal, handliner 18 m	486	9%
	Senegal, canoe 8 m	1,215	21%
	South Africa, rock lobster	15,147	17%
Caribbean	Barbados, day boats 8 m	10,206	56%
	Barbados, ice boats 13 m	5,913	8%
	Barbados, open boat 7 m	25,272	21%
	Antigua, open boat 6 m	3,564	34%
	Antigua, cabin boat 7 m	4,698	29%
	Antigua, sloop 10 m	-4,212	n/a
	Antigua, launch 11m	18,468	38%
	Antigua, launch 12 m	24,422	41%
Asia	India, non-motorized 5.5 m	810	163%
	India, motorized 8.5 m	1,296	61%
	India, dolnetter 9-12 m	2,997	61%
	India, stern trawler18 m	3,969	17%
This study	PD vessel, 12 m	3,938	37%
	TN vessel, 9 m	1,036	15%
	HL vessel, 9 m	1,110	23%
	LF vessel, 14 m	6,969	16%

Note: The original ANP was converted from US$ to GBP using the fixed currency rate of £0.81.
Source: (Tietze *et al.*, 2005)

The amount of profit is influenced by the total revenue, sharing system and the number of fishers. The total revenue is directly linked to the catch per trip, fuel consumption, fish price and fuel price. As a result, the improvement can be elicited by several constructive changes in those variables. Unlike other vessels, the owner of the PD vessel is responsible for the entire operational cost (see Figure 3.17), thus, in this case, fuel price will not affect the fishers' profit.

The sharing system is part of the culture, which is formed as a consequence of the high risks associated with the fishing industry (Satria, 2015). The portion of the share usually follows the customary law of the local community. Thus, the share varies depending on the characteristics of the fishing community and the fishing gear. In fact, the Indonesian government regulates the minimum sharing for fishers, and as discussed in Section 4.2.4 only the PD vessel which comply with the regulation.

According to the applied sharing system in each vessel, described in Section 3.5, the net revenue in the PD, TN and LF is shared between the owner and the vessel crew as a group. Subsequently, the crew's portion is equally distributed based on the crew size. This means that the number of fishers working on board does not affect the owner's share, yet it affects the fishers individually, seeing as the smaller crew results in a greater share. However, unlike other vessels, the net revenue in the HL vessel is shared equally between the owner and the fisher as an individual. This means the number of fishers in the HL vessel will directly affect the owner's profit. Furthermore, in the LF vessel the number of fishing gear also affect the owner's profit, as the gear is operated separately by other fishers.

6.3.5 Life cycle cost

The most significant component in the life cycle cost (LCC) is supplies and personnel costs, which respectively constitute 38% and 45% in the PD vessel, 28% and 47% in the TN vessel, 25% and 56% in the HL vessel and 35% and 34% in the LF vessel (Table 5.10). No comparable LCC result can be referred to in order to evaluate the performance of the studied vessels. However, from the economic performance of worldwide SSFV reported by Tietze *et al.* (2005), the annual fishing costs can be detailed into operational costs, as seen in Figure 6.8 and therefore, it can be compared with the operational expenditure resulted in this study. The figure confirms that the domination of fuel and labour expenditure is found in the fishing operations in most places.

Supplies cost is mainly associated with the fuel, whilst personnel cost is linked to the sharing system and catch per trip. Therefore, it can be said that the enhancement in LCC can be carried out through a constructive adjustment in catch per trip, fuel consumption, fuel price, and the sharing system. These concerns are relevant with all vessels, as the cost is a crucial issue in the fishing business.

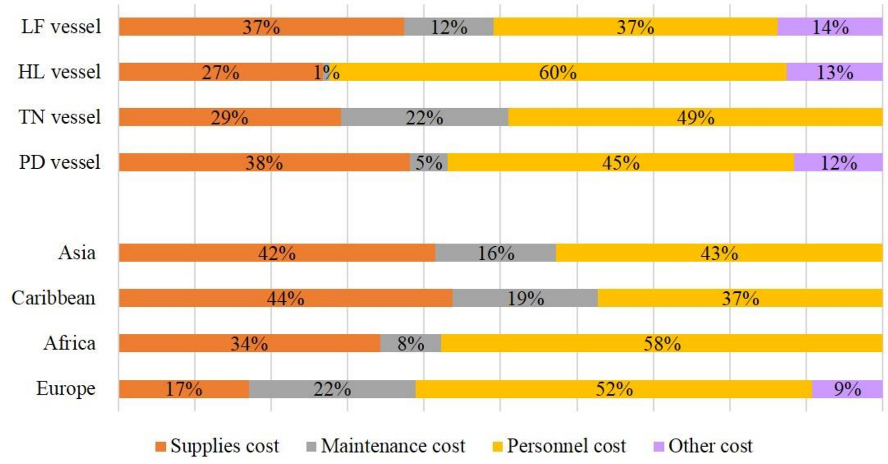


Figure 6.8 Operational and maintenance expenditure (OPEX) breakdown of SSFVs globally

6.3.6 Financial analysis

For the long term period, the economic performance of the fishing operation is also presented in financial analysis consisting of NPV, PP and IRR. In Figure 5.15, the analysis results reveal that all the studied operations are viable fishing businesses. Being set in three different scenarios: common, optimistic and pessimistic, the result suggests that the number of successful trips significantly influences the cash flow of the PD and TN vessels.

6.3.7 Social life cycle assessment

According to the social life cycle assessment (S-LCA), the largest gaps are noticed in human rights, working conditions and health and safety, which indicate that enhancement in those areas has the potential to improve social performance. Furthermore, by examining the detail calculation presented in Appendix P, concerns should be given on subcategories which contribute the highest gap, i.e., child labour, a fair salary, health and safety, and social benefits. These concerns are relevant in all vessels, as fishing community from the four studied vessels is homogenous.

6.4 Identification of possible measures for improving environmental performance

According to Section 6.3, at least 12 areas for potential improvement are identified in relation to environmental performance. Regarding each concern, the following paragraphs discuss the possible measures in both practical and policy levels, which is summarised in Table 6.5.

Table 6.5 Summary of possible measures to improve the environmental performance

Area for improvement	Possible measures	
	Practical level	**Policy level**
1. Fuel consumption	• Optimise the hull maintenance interval • Participate in the LPG conversion programme • Manage the speed appropriately • Participate in the research and development programme • Participate in the fibreglass conversion programme • Break from fishing during the low season	• Promote the LPG conversion programme • Support research and development of sustainable fishing vessel design • Promote the fibreglass conversion programme • Implement the seasonal fishing ban
2. Catch per trip	• Develop awareness of ecosystem quality • Prevent over fishing in the bay	• Fish stock assessment specifically for Palabuhanratu Bay • Propose management action which considers economic and social impacts
3. Fish price	• Develop solid and mutual collaboration	• Encourage the seller to be involved in improving fisher's wealth • Maintain fish prices • Activate a proper auction mechanism
4. Fuel type	• Participate in the LPG conversion programme	• Promote the LPG conversion programme
5. Ice consumption	• Reduce the ice quantity during the low season	N/A
6. Lubricant consumption	• Change the main engine from a 2-stroke to a 4-stroke engine • Switch from night-time to daytime operations	N/A
7. Electricity consumption	• Install additional fenders • Treat the wood before construction • Develop good manoeuvring skills	• Develop renewable energy for Small & Medium Enterprises (SMEs) • Develop a greener method for existing electricity production
8. Hull maintenance	• Optimise the hull maintenance interval	N/A
9. Paint use	• Optimise the hull maintenance interval	• Support research and development of environmentally friendly paint and anti-fouling
10. Fish container	• Change the EPS box to an HDPE or a fibreglass box	N/A
11. Plastic drums	• Use second-hand plastic drums • Optimise the platform size	N/A
12. Wood use	• Participate in the fibreglass conversion programme	• Promote the fibreglass conversion programme

6.4.1 Fuel consumption

Fuel consumption is the most significant contributor for both environmental and economic impacts. As fishing is also highly dependent on fuel, its optimisation is becoming more challenging.

Table 6.6 illustrates the impact of fuel reduction on the environmental performance of the PD vessel. A reduction of 5 litres per fishing trip in the PD vessel will improve the FUI_{kg} by 0.02 and ep-EROI by 0.01. Regarding life cycle impact, this change reduces the impact by 0.01 mPt or equal to 4% of the total impact. Considering the percentage of impact derived from other fishing inputs (see Table 5.8), this percentage is considered to be significant. Furthermore, economically, this reduction increases the owner's profit by £497 or 9 % of the total annual profit.

Considerable energy use in the fisheries sector has led to numerous studies focusing on the development of energy efficient fishing, which resulted in either practical recommendations to reduce fuel use. The following paragraphs discuss the applicability of some suggestions for fishing vessel operations in Palabuhanratu.

1. Periodical hull cleaning

   According to Latorre (2001), a periodical hull cleaning reduce fuel consumption by 30%. Currently, both the PD and TN vessels schedule hull maintenance every three months, whilst the LF vessel is every four months. Increasing the cleaning frequency will raise the environmental load and expenditure. Hence, suggesting a modification for periodical hull cleaning requires further consideration of its impacts relative to the total impacts and financial consequences. As described in Tables 6.2 and 6.3, hull maintenance is one of the concerns regarding the sustainability improvement which is further discussed in Section 6.4.8.

Table 6.6 Impact of fuel reduction on the environmental impact of the PD vessel

Fuel reduction/ trip (litres)	FUI		ep-EROI	CO2		E-LCA (mPt)		Owner's profit/year (£)
	per kg	per £		per kg	per £	per kg	per £	
0	0.38	0.69	0.18	0.91	1.66	0.26	0.47	5,806
-5	0.36	0.66	0.19	0.87	1.58	0.25	0.45	6,303
-10	0.34	0.62	0.20	0.82	1.49	0.24	0.43	6,800
-15	0.32	0.59	0.21	0.78	1.41	0.23	0.41	7,297

2. LPG conversion

According to Murillo *et al.* (2008), LPG is only suitable as a petrol substitute for low power engines, whilst for middle or high-power engines, diesel remains the best choice for marine use. This means the LPG conversion will applicable for the small-scale fishing vessels that use petrol fuel.

Conversion from petrol to LPG will require additional investment and skills to operate the engine. In this case, the government should be involved in the introduction and promotion process, to assist it to be applicable in the fishing sector. Subsequently, the fishers should be encouraged to learn and adapt to this technological advancement.

In Indonesia, LPG conversion in fishing vessels began in 2010 with the invention of the Amin Ben-Gas (ABG) conversion kit, which allows the vessel to use LPG. It is claimed that to run the engine for one hour, the ratio of petrol to LPG consumption is 3 to 1, whilst the cost ratio is 5 to 1 (http://aminbengas.com, 2018). As a result, this successful invention produced the national conversion programme for fishing vessels less than 5 GT. In order to support this programme, the government provides free converter kits and issued a national regulation which guarantees the continuity of LPG for small-scale fishers.

3. Speed management

Speed and fuel use during the fishing process can be monitored using a fuel meter. For the advanced level, a software can be installed on the vessel to audit and manage the fuel use (Basurko *et al.*, 2013). Concerning the technical level of the studied vessels, it is challenging to adopt that particular technology. Hence, a possible solution at the practical level is that the skipper should understand the characteristics of the engine and run the vessel responsibly. Usually, these skills are found in an experienced skipper. Thus, knowledge transfer amongst the skippers is required in order to increase awareness of saving fuel.

In Section 4.3.2, the profile of fishing vessel operations has been mapped and it is showed that the highest speed and fuel consumption in all studied operations are found during steaming. Using the same operational profile, a rough estimation is made in order to investigate the impact of speed reduction on fuel consumption, and the result is presented in Table 6.7. The table suggests that the speed reduction is potential to be proposed to improve the environmental performance. Furthermore, at the policy level, the government should monitor the energy use against fish production by improving the data collection system, which records not only successful trips, but also unsuccessful ones.

4. Redesigning the vessel

Redesigning the hull, propeller and the gear has the potential to increase fuel efficiency (Caslake and Garrett, 2009; Priour, 2009; Schau *et al.*, 2009). This measure might be excluded as it is related to additional investment and has the potential to distract the fishers' habits, unless, the improvement considers the socio-economic impact on the fishers. According to Wibawa (2016), when promoting a sustainable design to the fishers, the proposed design should consider their indigenous characteristics and familiarity in order to increase its acceptability. Furthermore, when dealing with the introduction of technical advancement, the fishers usually disregard this aspect until it is confirmed that it will improve the existing practices. Nevertheless, during the research and development process, they were happy to collaborate.

5. Fibreglass conversion

Fibreglass conversion could also reduce fuel consumption, as it lightens the vessels' weight in addition to the engine load. Similar to the redesigning solution, converting a wooden material into fibreglass requires further communication with the fishers as the users and consideration of local values. The discussion about the fibreglass conversion is presented in Section 6.4.12.

Table 6.7 Impact of speed reduction on fuel consumption

Fishing vessel	**Steaming speed (knots)**		**Fuel saving**	**Increase in steaming time**	**Total fuel use (litres)**
	From	**to**			
PD vessel	7.45	6.45	11%	15%	85.12
TN vessel	6.48	5.48	14%	18%	17.62
HL vessel	6.29	5.29	21%	19%	4.03
LF vessel	6.70	5.70	23%	18%	17.28

6. Seasonal ban

According to Driscoll and Tyedmers (2010), a seasonal ban could possibly improve energy efficiency in fishing. However, by doing this, there will be some negative consequences for the fishers and fish supply. As illustrated in Section 4.2.2, the intensity of the fishing operations in Palabuhanratu is highly dependent on the season. Fishing is conducted throughout the year, although during the low season, the fishers reduce their effort due to bad weather or low productivity. Therefore, it is proposed that fishers voluntarily stop their efforts or for the government to ban operations during the low season. This solution is expected to improve either the safety issue or fish stock replenishment. However, it means that there will be no income for fishers, as fishing is the only form of employment they have. Furthermore, most fishers have limited skills that compound the problem of finding a substitute job if fishing is prohibited. Hence, enhancing the fishers with additional skills is a necessity to reduce the financial difficulties during the low season. In this case, the fishers should encourage self-development, whilst the government should provide support by way of the capacity building programme.

7. Route planning

In the shipping world, planning the optimum route is beneficial to improve energy efficiency (Torres *et al.*, 2010). However, it is impracticable for SSFV, as the fishing grounds are relatively close. Furthermore, especially regarding the PD vessel, even though the main fishing ground is regularly planned, the route might be changed at any time depending on the fish abundance.

6.4.2 Catch per trip

As the output of the fishing operations, catch per trip is the key in defining the environmental and economic impacts. The increase in the catch per trip will significantly improve the performance of fishing operations. However, the statistics show that there is a declining trend in fishing productivity, as described in Figure 6.9. Furthermore, fishers also confirmed that they caught less fish than previously. This fact suggests that increasing fishing productivity is virtually impossible. Therefore, the best practice that might be suggested is maintaining the fish stock at a sustainable level, which can be

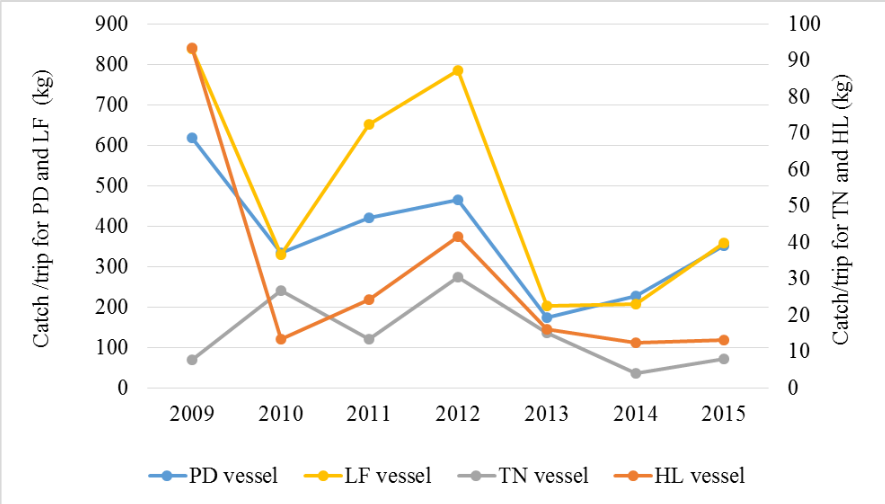


Figure 6.9 Catch per trip of studied vessels from 2009 – 2015
(PPN Palabuhanratu, 2015)

achieved via several measures. At the practical level, the fishers should be aware of the quality of the ecosystem, such as avoiding undersize fish and destructive fishing gear. Besides, the fishers should actively participate to prevent overfishing in the bay. At the policy level, fishery management should start with a fish stock assessment specifically for Palabuhanratu Bay. Thus, reliable and accurate data is required to support the decision-making process, which is applicable for the region.

6.4.3 Fish price

Fish price is highly dependent on supply and demand and is very challenging for fishers to negotiate the price due to low bargaining positions. Most fishers are bonded with an agreement to sell their catch through the seller, a broker or a trader who is also the creditor. This mechanism allows the seller to interact with the fish buyer and to negotiate the price. In the PD vessel, for example, the seller is actually the trader, who sets the price and leaves the owners with no choice. In this case, the seller receives double incomes from both the vessel's selling cost and the margin price when selling to the third party. Even though the sellers do not benefit the fishers in terms of price negotiation, they plays an essential role in providing financial support and a guarantee of sales. In some cases, the sellers are also the capital holder, which implies that they are the real businessmen.

Given the structure of the value chain, it means that the improvement in the economic performance through fish price is not in the fisher's or owner's domain, but that of the sellers and the government. The sellers should acknowledge the fishers by developing a solid and mutual collaboration. A negative impression is usually attached to the sellers as they control both fishers and the market. Therefore, the government should encourage them to be involved in improving the fishers' prosperity and maintaining the fish market. Furthermore, government intervention is required to control the stability of the fish price.

The use of an auction is also another potential improvement, as the fish will be sold at the best rate. There is an auction facility inside the fishing port operated by the fisheries council. However, the auction is not optimally operated due to insufficient financial support and a poor management system. Consequently, most fishers ignore this option and prefer to collaborate with the sellers. In order to enhance the auction, the operator should improve financial support, internal management and promotion activities.

6.4.4 Fuel type

Fuel types are linked to the production of CO_2 emissions. Two types of fuel used for fishing operations are petrol and diesel, which according to Lemigas (2014), potentially emits 72.97 and 74.43 tons CO_2/TJ fuel consumption. In order to reduce the emissions, conversion to LPG could potentially improve the environmental performance, as it has a lower CO_2 emissions factor, which is 63.10 ton/TJ (Intergovernmental Panel on Climate Change (IPCC), 2006). Fuel conversion or substitution is not planned at the practical level as the government should be involved in supporting and promoting the use of LPG in fishing operations.

6.4.5 Ice consumption

Ice consumption is becoming an issue due to electricity consumption during its production. According to the local producer, about 0.13 kWh is required to produce a 1 kg ice block, which is the typical production capacity of the commercial ice block machine. This indicates that electricity consumption has actually reached the optimum level. Hence a further saving in consumption is virtually impossible.

Alternatively, a possible practical measure that can be accomplished is reducing ice consumption. However, it should be noted that proposing a further reduction will put the quality of fish at risk and moreover, could affect the price. Typically, the PD vessel transports 62.5 kg of ice, whilst the TN and HL vessels carry 25 kg each. Following the principle of the fish cooling system as suggested by Shawyer and Medina (2003), the ratio of ice to fish is already ideal for both the TN and HL vessels, as on average, the catch in both vessels is 13 and 18 kg respectively. Conversely, it is disproportionate for the PD vessel, given the catch is 266 kg/trip.

One block of ice weighs 50 kg and is typically sold in units of a quarter, half or one block. For practical reasons, the fishers usually buy the same amount of ice per trip, unless it is predicted that there will be a substantial catch. Therefore, the proposed improvement is carrying less ice during the low season, especially for the TN and HL vessels. By purchasing a quarter block instead of a half block during the low season, the amount of ice can be reduced by 450 kg/year, therefore, the environmental impact will decrease by 105 mPt (2.9% of the total impact). Regarding the impact contribution of other fishing inputs, this reduction is considered significant. In economic terms, this reduction will slightly increase the fishers' profit by £2/year in relation to TN vessel and £4/year regarding the HL vessel, as seen in the sensitivity analysis (Appendix N). It is insignificant because ice is not an expensive item.

Using an ice pack has become more popular recently. It is claimed to reduce fish preservation costs by up to 70% for a 3 year period (Bhakti Nusa Bahtera (BNB), 2018). However, given the fact that not every household has a freezer to renew the ice pack, it presents another challenge. Furthermore, according to Shawyer and Medina (2003), for the best preservation, the ice block should be crushed or mixed with water. Thus, ice pack application during the fishing process might be inappropriate.

6.4.6 Lubricant consumption

The issue related to lubricant is found in the operational stage of the PD, LF and HL vessels. This is primarily due to the use of a two-stroke engine as the main engine in the PD vessel and generator in the HL and LF vessels, which require a lubricant to be mixed with the petrol using a ratio of 30:1. Thus, the best practice to reduce lubricant use is reducing fuel consumption, which has been discussed in Point 1.

An additional recommendation is switching to a four-stroke engine that does not require its fuel to be mixed with lubricant. This change will reduce not only the lubricant consumption but also fuel consumption and emissions. However, there will be an additional cost since the four-stroke engine is significantly more expensive than its counterpart. Regarding the environmental improvement, the idea of changing to the four-stroke engine will be discussed with the fishers, even though it is an economic burden.

Furthermore, although most HL fishing is conducted during the night-time, sometimes it can be conducted during the daytime, which means a generator is not required to produce electricity. This means switching operations from night to day also has the potential to reduce lubricant consumption.

6.4.7 Electricity consumption

In this study, the impact of electricity consumption was calculated using the background process generated by Treyer (2015). It is revealed that the impact of electricity consumption in Indonesia, especially on human health, significantly exceeds other countries, such as China, India, the UK, the US and Europe. This is principally because the emissions from electricity production in Indonesia are higher than in other countries. The pollutants primarily consist of particulates less than 2.5 µm ($PM_{2.5}$), nitrogen oxides (NOx) and sulphur dioxide (SO_2) might be derived from coal and other fossil fuels**,** as both materials are used as the major inputs to produce electricity. In Indonesia, renewable energy sources, such as solar, wind power, geothermal and biomass are poorly developed, particularly for small-scale consumers. Hence, electricity generated from coal and fossil fuels continue to be the primary sources of energy.

The electronic devices used during the production and maintenance process are low-powered devices ranging from 120 to 450 Watts, with an operational time of between 4 – 6 hours/day depending on the working load. When the vessel is built or repaired, the electricity bill is included in the total cost. Therefore, the fishers or the builder will not be aware of its consumption. It is also mentioned in Point 5 that in regard to ice production, electricity consumption has been optimised. In addition, according to (OECD/IEA, 2014), electricity consumption in Indonesia is low compared to other neighbour countries, in 2014 it is reported that electricity consumption per capita is 812 kWh per year.

Seeing as consumption is already low, suggesting further savings will also be challenging. Therefore, possible measures that can be proposed at the practical level is encouraging the fishers to protect their vessels, especially wooden vessels, from mechanical damage. Consequently, working loads requiring electricity such as sawing, grinding, planning and drilling can be minimised. By assuming that all variables remain constant, the reduction in 1 kWh of electricity consumption in the maintenance of PD and TN vessels reduce the impact by 10.5 mPt and is approximately 8.1 mPt per year in the LF vessel, which is insignificant compared to the impact contribution of other fishing inputs. Electricity consumption in the HL vessel is minor, therefore, no further analysis is carried out. Furthermore, at the policy level, the Indonesian government should develop renewable energy and greener methods for existing electricity production. Further details about preventing mechanical damage is provided in the next section.

6.4.8 Hull maintenance

In order to prevent mechanical damage, protection can be completed via several measures, such as fender installation, wood preservation and good manoeuvring skills, which are described below. Second-hand car tyres are a popular fender type installed on the fishing vessels. They are inexpensive, easy to obtain and considered part of reusing used tyres, and therefore, will not affect economic and environmental performance. These movable fenders are found in most vessels but comprise only 1 or 2 pieces. More fenders should be added in order to provide optimal protection. Additionally, as it is inexpensive, this addition will not affect business cash flow.

Due to financial reasons, good quality wood is only used for the underwater area and the main frames. Alternatively, lower class wood is used for the freeboard, deck and superstructure. According to the builders, no special treatment was performed prior to the construction. Thus, in order to increase its physical properties, wood preservation is required. This can be completed through impregnation with chemicals substances, wood compression and heating treatments. A study conducted by Nandika et al. (2015), revealed that the combination of those three methods is proven to increase the strength of softwood from fourth to second class. Given that the study is still being undertaken in the laboratory, further experiment is required prior to introducing this method to the public. Furthermore, government support is required to develop and promote the use of less well-known wood as an alternative to typical wood for boat building. In contrast, fishers and boat builders should consider wood preservation, for instance heating and soaking prior to construction.

Palabuhanratu fishing port has two terminals. The 1st terminal is designed for small vessels, whilst the 2nd terminal is for larger ones (Figure 6.10). The large number of small boats has made the 1st terminal crowded in the morning and late afternoon as the vessels enter and leave the marina. The berthing area is limited, so the vessels are usually tied together before and after being moored on the quay for loading and unloading. It is common for vessels to bump into each other and cause some minor damage. One of the respondents stated that

Figure 6.10 Satellite view of Palabuhanratu fishing port
(Google, 2018)

> *"The most vulnerable parts are the port side, starboard and stern. That part (pointed at the broken sides) was bumped. Turn right bumped, turn left bumped. Bumps are very common here" (Respondent O.4.0.2).*

Therefore, in order to prevent the vessels from crashing, excellent manoeuvring skills are required around the terminal.

The frequency of hull maintenance is becoming an issue in regard to the LCA of wooden vessels. Over the course of one year, a wooden vessel requires approximately 3-4 periods of maintenance. Reducing the annual frequency might increase the quantity of the materials and resources used per task due to the cumulative damage and working load. This means that the cost will follow. Therefore, the improvement that will be proposed is optimising the maintenance period. To do that, however, further analysis on the accumulation of the vessel's resistance as a result of an additional month is required, including its impact on the increased fuel consumption, materials and its cost.

The analysis will not be discussed in this study, instead, a rough estimation is made using the LCA model and fishing operation model. It should be noted that the assumption is made based on the researcher's judgment.

For example, it is assumed that the repainting work undertaken on the LF ferry (excluding the platforms) will be reduced from three (3p) to two (2p) times per year. If the repainting inputs remain constant, this reduction will decrease the annual impact by 43 mPt, from 390 to 347 mPt. However, if this reduction increases the painting materials and resources, a rough estimation of its effects on reducing the environmental impact is presented in Figure 6.11. The figure shows that in the case of painting load increase up to 20%, extending the period for repainting work from four to six months will improve the environmental performance.

However, lengthening the maintenance interval might increase fuel consumption. Hence, this response should be considered. For example, the simulation result shows that an increase of one-litre of fuel per trip in the LF ferry increases the environmental impact up to 97 mPt, which is greater than the reducing impact resulting from the repainting work. Therefore, it can be concluded that extending the maintenance interval does not necessarily improve the environmental performance, seeing as there will be an additional impact generated by the increase in fuel consumption. Nevertheless, from an economic perspective, increasing fuel consumption and maintenance cost up to 10 litres and 100% respectively still results in viable cash flow.

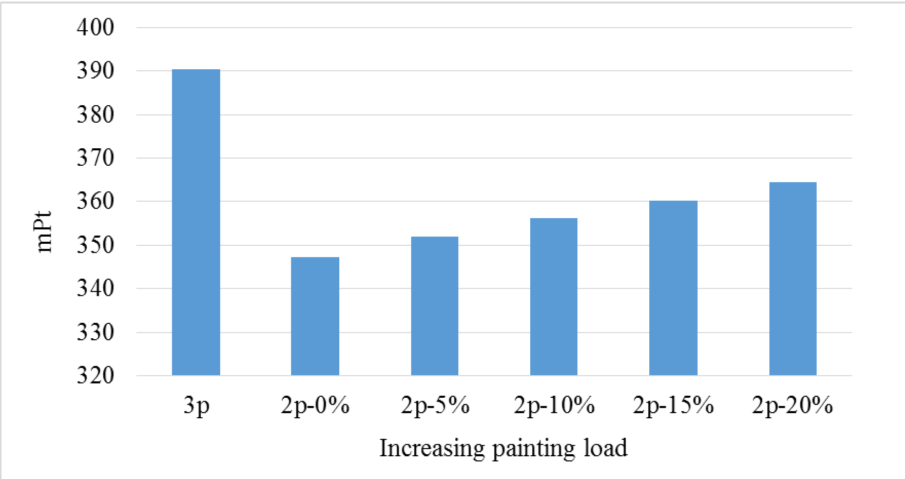


Figure 6.11 Impact on increasing painting load on the LF vessel

6.4.9 Paint use

Paint use refers to the quantity and type of paint and anti-fouling. The quantity is linked with the frequency of the hull maintenance (Section 6.4.8). Regarding type of paint, the potential improvement is suggested through modification of the material composition of the paint and anti-fouling. No practical suggestion is proposed, as the fishers usually buy the products that are available on the market and their preferences are mostly driven by price and quality. Therefore, the improvement should be made at the policy level by supporting the research and development of the environmentally friendly paint and anti-fouling, because it is not only beneficial for fishing vessels but also for the national shipping industry.

6.4.10 Cool box material

The EPS cool box is the most common fish storage method used in the region. In the HL and TN vessels, the EPS cool box is preferable due to its practicality to store both ice and the catch. The catch is not as considerable as the other vessels, thus a cool box with 100 litres capacity is used. In fact, there is a space underneath the deck that can be used to store the fish, but since it is not insulated, the fishers rarely use it. An EPS cool box is inexpensive and has a short lifetime which typically lasts for about one month. Consequently, at least 12 boxes are required to support one-year operations.

In order to reduce the environmental burden from fish containers, substitution to high-density polyethene (HDPE) or fibreglass cool boxes can be proposed. Both materials are more expensive, approximately 10 times higher than the EPS cool box price. However, the boxes are durable, sturdy and reusable for up to 2 years. No information related to the environmental impact of both cool boxes is found. However, a study on European fish packaging conducted by PwC Ecobilan (2011), revealed that in general, EPS material performs better than polypropylene (PP) material with respect to one-time usage. Even though it is not an equal comparison, this suggests that the EPS cool box might also perform better than the HDPE and fibreglass cool boxes. Nevertheless, the fact that those two materials are more durable and long lasting might increase its environmental performance. Therefore, despite insufficient scientific support, the idea of using HDPE or fibreglass cool boxes will be communicated further with the fishers.

6.4.11 Plastic drums

Plastic drums are used as the base for the bamboo platform in LF fishing. Prior to being partially floated using the plastic drums, the platform is attached to the wooden vessel. Subsequently, plastic drums have been widely used due to the low price and efficiency. The number of plastic drums used for one platform varies from 12 to 20 drums depending on the size of the platform, though most use 18 drums. Either new or second-hand drums can be used as long as they are leak-proof. Before installation, the drum and its lid are sealed. After that, no special maintenance is performed once it is tied to the platform. When there is a leak, it will be replaced immediately.

A plastic drum is also used as a fish container in the PD vessel, even though there is a space under the deck that can be used to store the fish. However, the fishers prefer to use plastic drums simply for practical reasons, as the fish will be easily landed and transported. The impact of drums in the PD vessel is minor, hence, it will not be discussed any further.

According to the principle of LCA, using new and used drums will generate different impacts. Reusing a plastic drum means that its environmental burden can be considered as part of its previous utilisation phase, such as for chemical transportation. The inputs from raw material and the production process can be omitted, therefore, the environmental impact can be reduced. A further method to reduce the impact from the plastic drums is using a smaller platform. Thus, the number of drums can be minimised.

The plastic drum is extremely popular as a base for the LF platform, not only in Palabuhanratu but throughout Indonesia. Changing the types of platform base with other materials such as steel drums, bamboo or a fibreglass vessel might reduce the environmental impacts. However, further analysis shows that the drum is still the most feasible alternative, both environmentally and economically, as explained below.

A study conducted by Manuilova (2003), concluded that compared to a steel drum, a plastic drum is more environmentally friendly. Besides, a brand-new steel drum costs nearly double the price of its counterpart.

Regarding bamboo, there are some small platforms in other regions that use bamboo as the base (Figure 6.12a). However, given the platforms in Palabuhanratu are large constructions weighing up to 3.6 tonnes, more than 100 pieces of bamboo with a diameter of 8 cm are required in order to provide the same function. Although bamboo has a lower environmental impact, it is costly compared to the plastic drum, as one piece of bamboo costs the same as one plastic drum. Using a bamboo base might be feasible if the existing assembly is modified into a lighter construction. Accordingly, further analysis is required.

An LF platform can also be built on one or two vessels (Figure 6.12b and 6.12c). Using a wooden vessel will undoubtedly generate a higher impact, thus, a fibreglass vessel can be the possible alternative. However, simulation using the existing model shows that plastic drums perform better than one or two fibreglass vessels, as described in Figure

6.13. Besides, plastic drums are undoubtedly inexpensive in contrast to the vessel. Inventory data used for the fibreglass vessels is provided in Appendix Q.

The above explanation concludes that a possible measure is using a second-hand drum and optimising the platform size. In this study, all plastic drums were assumed to be a new product, contributing a 63 mPt impact which is equivalent to 0.5% of the total annual impact of the LF vessel. It means using the second-hand drums might reduce the impact by 63 mPt per year. Furthermore, using a used drum is also more economical as it is 77%

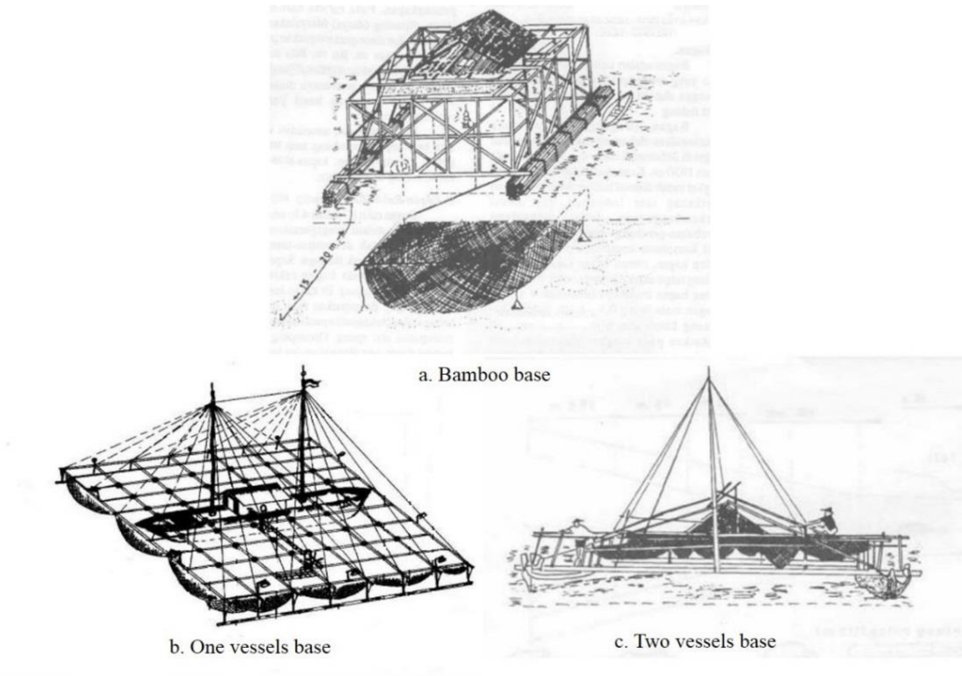


Figure 6.12 Alternatives for the base of the LF platform
(Genisa, 1998; Sudirman *et al.*, 2006)

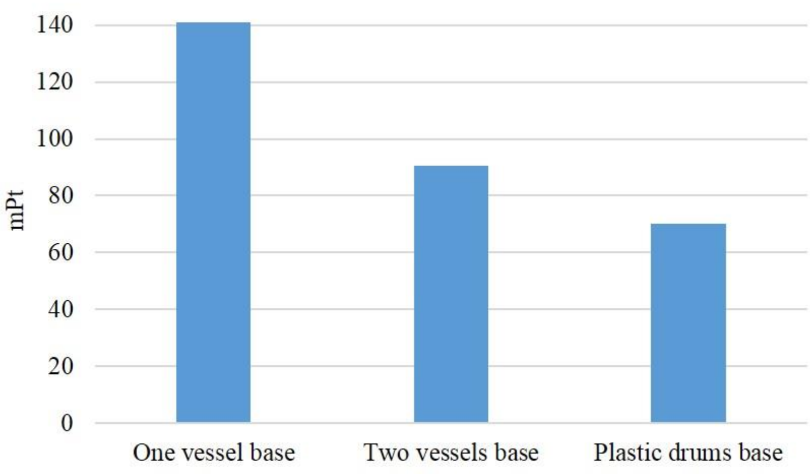


Figure 6.13 LCA result for different types of LF platform base

cheaper. Nevertheless, according to the fishers, finding a used drum which meets the requirements is sometimes challenging, therefore, they just mix used and new drums. In addition, regarding optimum size, further investigation is required to analyse the effect of different platform sizes on productivity.

6.4.12 Wood use

Wooden material affects the result of the LCA due to the requirement for frequent and periodical maintenance. As seen in the inventory analysis (Appendix J), the wooden vessels (PD, TN and LF vessels) require maintenance three or four times per year, whilst the fibreglass vessel (HL vessel) only needs maintenance once in three years. Replacing the wooden material with fibreglass might be a solution to the challenge. The following paragraphs analyse this possibility.

At the same size**,** the resources inputs for a fibreglass vessel is smaller than a wooden vessel. However, according to Wibawa (2016), wood is the most environmentally friendly material, followed by laminated wood and fibreglass. Furthermore, Landamore *et al.* (2006), also confirmed that the environmental performance of the wood-epoxy boat exceeds the fibreglass boat. Indeed, at the production stage, the fibreglass boat is not the best choice, nevertheless, its performance during the operational stage should be considered as a potential improvement for reducing the life cycle impact. In economic terms, Landamore *et al.* (2006), also revealed that the LCC fibreglass vessel is more economical than the wood-epoxy vessel.

A rough estimation has been made in order to evaluate the prospect of the fibreglass conversion. The example here is simulated for the hull of the PD vessel. In this scenario, a fibreglass hull is proposed with the same dimensions as the existing vessel. Accordingly, the projection for the LCA and LCC results is presented in Table 6.8, whilst the effect on the cash flow is shown in Table 6.9. The supporting data to generate the calculation is provided in Appendix R.

Table 6.8 shows that the production cost of a fibreglass boat is higher than the wooden boat. Similarly, a study conducted by Wibawa (2016), also reveals that the production cost per cubic number (CUNO) for wooden and fibreglass vessels constructed in East Java Indonesia is £147 and £222 respectively. Even though the production cost is higher, the maintenance cost of a fibreglass boat is insubstantial. Consequently, it has a positive impact on the financial situation. Furthermore, in Table 6.9, it can be seen that even though the pessimistic scenario is used, the operation of the PD vessel using a fibreglass boat is still feasible.

The table confirms that the fibreglass conversion of a wooden boat into a fibreglass vessel would be beneficial due to low maintenance. However, in order to achieve the goal successfully, the government should communicate with the fishing community, as it requires further consideration with respect to local values and habits.

Table 6.8 Impact of fibreglass conversion on LCA and LCC simulated for the PD vessel

Impact indicators	Hull production		Maintenance/year		End of life	
	Wood	Fibreglass	Wood	Fibreglass	Wood	Fibreglass
E-LCA (mPt)	1451	1962	292	69	8	6
LCC (£)	2718	3624	1364	114	60	45

Table 6.9 Impact of fibreglass conversion on financial analysis simulated for the PD vessel

Hull material	NPV (£)			IRR		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
Wood	20,923	47,822	-5,982	73%	96%	0%
Fibreglass	39,021	65,924	12,119	83%	100%	39%

6.5 Identification of possible measures for improving economic performance

According to Section 6.3, 9 areas for potential improvement are identified in relation to economic performance. Three of them, i.e. fuel consumption, catch per trip and fish price have been discussed in Section 6.4. Therefore, the following paragraphs discuss the remaining areas, which are subsequently summarised in Table 6.10.

6.5.1 Number of successful trips

In traditional fishing practice, the fish searching process is carried out manually by relying on the presence of seabirds, the fisher’s visuals and instinct, or occasionally by taking a gamble. Hence, the fishing trip is not necessarily productive even though the gear is set many times. As seen in Appendix F, some trips catch nothing or produce a low catch whose revenue is not enough to pay for the operational costs. This situation will affect the daily income and long-term cash flow. The percentage of successful trips is modelled in three scenarios, specifically common, optimistic and pessimistic, which results in the ranges of income obtained from the fishing operations (Section 4.2.4).

Table 6.10 Summary of possible measures to improve the economic performance

Area for improvement	Possible measures	
	Practical level	Policy level
Number of successful trips	• Transfer knowledge amongst the fishers	N/A
Sharing system	• Amend the sharing system • Exclude the seller from the value chain	• Amend the law on the fisheries sharing system
Fuel price	N/A	• Maintain the fuel price through fuel subsidies
Number of fishers	• Define the optimum number of the crew • The owner is directly involved in the vessel operation to increase his share	N/A
Number of fishing gear	• Maintain the shuttling service to satisfy the fishers' need	N/A
Maintenance costs	• Keep costs at the existing level • The owner is directly involved in the vessel operation to increase his share	N/A

In order to increase the effectiveness of the fishing trips, the possible measures that can be suggested are using fish aggregating devices (FAD), such as lamps and *rumpon*, a device which can be drifted, floated and anchored in the water to attract fish. Lamps are used in the LF vessel. Given that the other fishing methods are conducted during the daytime and target demersal fishing, its application on other vessels is impracticable. Furthermore, the use of *rumpon* is now strictly regulated by the government due to its damaging impact on the ecosystem (MMAF, 2014). This fact suggests that in traditional fishing, manual methods remain the most relevant way to locate the fish. Thus, knowledge transfer is required amongst the fishers in order to increase their hunting skills. This skill is crucial for the PD vessel's crew, as fish locating stage consumes substantial amount of fuel.

6.5.2 Sharing system

The fisher's share, either regulated by the government or community, is considered low and that it is one of the major causes of poverty in the fishing community in Indonesia (Kusumastanto *et al.*, 2005). Therefore, the sharing system should be improved to allow the fishers to receive a greater share. However, seeing as fishers have a low bargaining position, which restricts them from negotiating with the owner or from changing the customary law, the government should be involved by changing the regulation. The minimum share for fishers should be increased after a certain period, at least when the investment cost has been paid off. Alternatively, according to the law, the owners should be encouraged to pay all the operational costs and should not share it with the fishers.

The results of the sensitivity analysis suggest that the sharing system can be changed in some fishing vessels to increase the fisher's profit. However, at the same time it should remain viable for the owner to run the business for a long time. Therefore, it is proposed that the PD and TN vessels increase the fisher's share up to 5% and 7% each. Regarding the HL and LF vessels, no change is required as the existing sharing system has produced the best share for both owner and fishers.

Another measure to increase the share is shortening the value chain. Applying direct selling has the potential to increase the net profit up to 10%, referring to the percentage of the selling cost. However, there are various consequences to deal with if no seller is involved in the distribution chain: financial difficulties when the owners or fishers run out of money to pay the operational costs because the seller is usually the creditor; requirement to build a market network to sell the catch; requirement to spend more time handling the fish after it is unloaded from the vessels.

6.5.3 Fuel price

Fuel price greatly affects the operational cost and different sharing mechanism results in various impacts regarding the shareholders and financial analysis. According to the sensitivity analysis, the increasing fuel price in the TN, HL and LF vessels will have a significant impact on fishers' profit, although a minor impact on the owner's income and the long-term cash flow. Reversely, in regard to the PD vessel, it intensely affects the owner and the financial situation, though it leaves the fishers unaffected.

Fuel price is set by the government. The price applied for the fishers is the subsidised price, which according to March 2018 is roughly 25% (for petrol) and 40% (for diesel fuel) cheaper than the actual price. Unlike the non-subsidised fuel, the price of subsidised fuel remains constant for a certain period, regardless of the fluctuation of the global oil prices. Therefore, improvement regarding fuel price should be made at the policy level by maintaining the price through fuel subsidies, as the percentage of the subsidies will relate to the political movements of the ruling government.

Figure 6.14 presents the history of fuel price compiled from legal documents issued to adjust fuel prices from 2000 to 2015. Despite several reductions, the fuel price shows a rising trend, which means that a further increase is likely to occur. Furthermore, compared to global fuel prices, Indonesia is included in the 30 (for petrol category) and 40 (for diesel category) countries with the lowest prices (www.globalpetrolprices.com, 2018). Meanwhile, Indonesia is ranked in third place as the country with the least expensive fuel in Southeast Asia. The fact that Indonesia is a notable player in the capture fisheries world, which is highly dependent on the fuel, underlines that low fuel price can be beneficial to generate more considerable margin when entering the global market.

Figure 6.14 Fuel price history in Indonesia from 2000-2015

6.5.4 Number of fishers

Table 6.3 shows that the number of fishers affects the fishers' profit in the PD, TN and LF vessel, though in the HL vessel it affects the owner's profit. The following paragraph explains how best practice can be proposed by considering the applied sharing system and number of crew.

In the PD vessel, the average of fishers working on board is 10 people. It is extremely rare for the vessel to go on a trip with a smaller crew. However, during the peak season, the crew might reach 15 people, as the skipper allows more people to work on board. Sensitivity analysis illustrates that the change in the number of fishers adjusts the individual income by at least £100/year. Therefore, best practice in relation to increasing the fisher's share is defining the optimum number of fishers working on board.

The LF platform is usually operated by one person. In the busy season, one more fisher might join as a helper whose share is agreed previously. As the leading fisher is one person, the possible improvement is encouraging the platform's owner to operate the platform alone and ask for help during busy periods. In this study, it is assumed that the platform is run by one fisher, who is not the owner and receives a 50% share. It means that if the platform is run by the owner directly, he receives 100% net profit.

The TN vessel is typically crewed by three people. If the fishing is very busy, the skipper will allow one more fisher to join. However, when performing passive fishing during the low season, it is sometimes operated by two people. Sensitivity analysis for the TN vessel shows that employing two fishers will increase the profit up to £400 per person per year, whilst if four people are working together, a potential decrease will be faced by each fisher of approximately £200. Therefore, similar to the PD vessel, the number of fishers should be maintained at the optimum level.

Even though the smaller crew allow the fishers to gain a more significant share, this means that they will have a higher working load. Therefore, reducing the crew should take into account the amount of work. In fact, instead of limiting the crew, the owner or skipper usually allows more fishers to work together as long as it does not exceed the capacity of the vessel. This practice, interestingly, does not bother the other crew members as they will receive the same share.

6.5.5 Number of fishing gear

The LF vessel consists of the ferry and platforms, thus the number of platforms served by each ferry is becoming a crucial issue in the LF vessel due to its direct correlation with the total catch and income. The platforms and the ferry are owned by different persons, who collaborate to conduct fishing operations as a group on the ferry basis. The fishers who operate the platforms always join in the same ferry, yet they are free to leave at any time. On average, the number of platforms served by the ferry is 10, which according to the model produces 90,456 kg fish per year. Following the applied sharing system, the additional number of platforms will increase the skipper and the ferry owner's profit and vice versa (Appendix N), therefore the best practice to maintain both skipper's and the ferry owner's income at the existing level is providing the good service for each platform, hence no fisher leave the ferry.

6.5.6 Maintenance cost

According to Table 6.3, maintenance cost significantly affects the financial analysis of the TN vessel, as the sensitivity analysis shows that the increasing cost of more than 33%

will lead to an impractical business. This is primarily because a large portion of the maintenance cost makes up to 45% of the annual income. Therefore, at the practical level, the measures that can be suggested are keeping the cost at the existing level and increasing the owner's share by involvement in the fishing operation. In the model, it is assumed that the vessel is run by other fishers. If the owner operates the vessel directly, there will be a potential increase in the annual profit by £834, which might reduce the percentage of the maintenance cost from 45% to 33%.

6.6 Identification of possible measures for improving social performance

According to Section 6.3, at least 4 areas for potential improvement are identified in relation to social performance. The following paragraphs discuss the possible measures regarding each concern, which are subsequently summarised in Table 6.11.

6.6.1 Child labour

The survey shows that there are children involved in the fishing operations whose ages range between 11 – 17 years old. They go to sea for several reasons, for instance family and money, and as it is also a hobby. As a hobby and for the family, the children usually

Table 6.11 Summary of possible measures to improve social performance

Area for improvement	**Possible measures**	
	Practical level	**Policy level**
Child labour	Encourage children to complete mandatory education	• Monitor the implementation of mandatory education • Protect the street children
Fair salary	• Amend the sharing system • Exclude the seller from the value chain	• Amend the law on the fisheries sharing system
Health and safety	• Enhance survival skills • Prepare first aid kits and safety equipment	• Conduct safety workshops • Ensure the availability of safety equipment on the fishing vessels
	• Communicate with other vessels or onshore partner to monitor the condition of the sea	• Improve accident handling
Social benefits	• Participate in the insurance programme	• Disseminate the insurance programme and monitor its implementation

go fishing during the weekend. Hence, it does not interfere with their formal school education. In fact, most fishers do not want their children to become a fisher and they only allow their children to go fishing when they are off school. However, for children who work as a full time or part time fisher, they have usually stopped or do not continue their study to a higher level due to motivation and family issues. For example, at first, the children join an experienced fisher as a helper, but later on, they enjoy being paid and decide not to continue their study. One of respondents said:

> *"I gave up my school already. I didn't continue to middle school. At first, I was just helping, but I found that it's easy to get money here. My father and brother are fishers, so I just follow them" (Respondent F.2.1.2).*

Furthermore, there are some street children who work around the fishing port as seen in Figure 6.15. Despite not knowing their parents, the fishers allow them to work because of sympathy.

In order to reduce child labour, the fishers should encourage teenagers to finish their compulsory education (until Year 9). Furthermore, the government should improve the monitoring system for the implementation of nine years mandatory education and the protection of abandoned children. In 2015, the government planned to extend the mandatory education to 12 years. However, discussion is still on-going. Besides increasing the educational level, extending the year might reduce the number of children participating in underage labour, not only in the fisheries industry but also in other sectors.

Figure 6.15 Children are working in the fishing port

6.6.2 Fair salary

Fair salary is associated with the amount of money received by the fishers and its adherence to the local standard payment. As mentioned in Section 6.3.4, the fishers' income is relatively low compared to the local minimum salary. As the payment is linked to economic impact, measures to increase the fishers' profit have been discussed in Section 6.4.2.

Another problem related to salary is the unpredictable amount of money obtained from fishing operations. Switching the sharing system to a monthly salary will solve the income irregularities. However, according to Kusumastanto *et al.* (2005), this system is not suitable for small-scale fisheries because of convenience, a strong belief that fishing is highly speculative and fluctuations in fish production. Furthermore, the sharing system is also prevalent in the fisheries world (Guillen *et al.*, 2017).

6.6.3 Health and safety

Health and safety aspects are commonly neglected in small-scale fishing operations because the fishers are generally confident with the fishing ground and with their working experience. At the practical level, the fisher should enhance their survival skills, carrying first aid kits and safety equipment, besides actively communicating with other vessels or onshore partner to monitor the sea situation. At the policy level, the government via the fishing port authority should conduct safety workshops to help the fishers improve their skills and ensure the availability of safety equipment on the fishing vessels. In addition, it is crucial that every accident that occurs in the bay should be handled competently.

6.6.4 Social benefits

The government provides health insurance for low income citizen including the fishers. Moreover, since 2017, the government has specifically provided accident and life insurance for fishers, as described in Table 6.12. When FGD was conducted in November 2016, the programme had not been launched nationally. Meanwhile, there is a claim that accident insurance has been implemented in the region by the local government (Fikri, 2017), yet very few fishers are aware of that. It means that the dissemination of the information should be improved.

Table 6.12 Coverage for accident and life insurance for fishers

Accident risks	Coverage
Death during the fishing operation	£12,000
Death during other activities	£9,000
Permanent disability	£6,000
Medication and treatment	£1,200

Source: (MMAF, 2017a)

Furthermore, the MMAF provides a fisher's ID card, as a tool to optimise fisher's protection and the empowerment programme. Most fishers have this card, although they are generally unaware of its purpose except for subsidies or grant programme. Toward this end, it is vital for the local government to communicate the programme with the fishers and monitor its implementation.

6.7 Best practice formulation

In this study, best practice refers to sort of measures that are practicable to be implemented to improve the sustainability performance. The following paragraph explains the result, which is presented in two parts: practical and policy levels. In each part, the degree of acceptability is presented in three categories, specifically, implemented, acceptable and unacceptable, and therefore, best practice to promote the sustainable development of the SSFV operations incorporate implemented and acceptable measures.

6.7.1 Practical level

According to Table 6.5, 6.10 and 6.11, thirty possible measures to improve environmental, economic and social performances are proposed, subsequently, through FGD, best practice was identified and the result is presented in Table 6.13. An implemented measure refers to an existing practice, an acceptable measure indicates that the community is interested, yet not sure about the result. Furthermore, an unacceptable measure means that the measure is strongly opposed by the community due to various reasons. The justification for each category is provided in Appendix S.

Table 6.13 reveals that most of the suggested measures have been implemented. Despite some partial implementation is found, this finding indicates that in general, the fishing community at the research site has performed a responsible fishing operation. According

Table 6.13 Degree of implementation at the practical level

Performance		Improvement Plan	Implementation		
			Implemented	Acceptable	Unacceptable
Environmental	1	Optimise the hull maintenance interval		√	
	2	Participate in the LPG conversion programme	√		
	3	Manage the speed properly	√		
	4	Participate in the research and development programme	√		
	5	Participate in the fibreglass conversion programme	√		
	6	Break from fishing during the low season			√
	7	Develop awareness of ecosystem quality	√		
	8	Prevent over fishing in the bay			√
	9	Develop solid and mutual collaboration	√		
	10	Reduce the ice quantity during the low season		√	
	11	Change the main engine from a 2-stroke to 4 stroke engine			√
	12	Switch from night time to day time operations			√
	13	Install additional fenders	√		
	14	Treat the wood before construction		√	
	15	Develop good manoeuvring skills	√		
	16	Change the EPS box to an HDPE or a fibreglass box			√
	17	Use second-hand plastic drums	√		
	18	Optimise the platform size		√	
Economic	19	Transfer knowledge amongst the fishers	√		
	20	Amend the sharing system			√
	21	Exclude the seller from value chain			√
	22	Define the optimum number of crew	√		
	23	The owner is directly involved in the fishing operation	√		
	24	Provide the best shuttling service	√		
	25	Keep costs at the existing level	√		
Social	26	Encourage children to complete mandatory education	√		
	27	Enhance survival skill	√		
	28	Prepare first aid kits and safety equipment		√	
	29	Communicate with other vessels or onshore partner to monitor the condition of the sea	√		
	30	Participate in the insurance programme	√		

to their explanation, economic reasons primarily drive their behaviour, as most implemented measures are associated with cost-effective interests. For example, the fishers are accommodating in relation to the technical conversion programme (i.e. LPG and the fibreglass boat), seeing as it could possibly improve their profit. On top of that, the programme is financially supported by the government. Thus, the additional cost is insignificant. This fact suggests that the acceptable measures have the potential to be implemented if it is proven to be beneficial. Furthermore, it clearly explains that the possible measures that are unacceptable are due to financial reasons.

6.7.2 Policy level

Regarding the policy level, 20 measures were proposed and Table 6.14 shows that 5 out of 20 suggested measures are actually being run as a national programme. However, it is not being fully implemented because the policy is not suitable for the present situation and moreover, due to technical support issues. For example, the LPG conversion programme is successfully accepted by various fishing operations, yet it is impracticable for some others. Furthermore, its implementation is hampered by the continuity of the

LPG supply, which essentially has been regulated. The justification for other measures at the policy level is provided in Appendix S.

Regarding acceptable measures, there are six measures listed in Table 6.14. Unlike the practical level, an acceptable measure in the policy level generally demonstrates that the recommendation is possible for future actions or it has been regulated already with poor implementation. The latter needs more evaluation as the regulation is neglected due to low awareness and weak law enforcement.

As mentioned in Section 6.2, the government referred to in this study is limited to the institution that is responsible for fisheries development in Palabuhanratu, including the port authority, local fisheries council and MMAF. Thus, the acceptability is only analysed from their perspectives. This suggests that an unacceptable measure does not only mean that it is practically hampered by the other factors but also beyond their authority. Six out of the nine unacceptable measures presented in Table 6.14 have been justified as being under the responsibility of other institutions, with concerns relating to energy, education, social welfare and research. This stresses that at the policy level, the promotion of sustainable fishing operations should be supported by non-fisheries institutions.

Table 6.14 Degree of implementation at the policy level

Performance		**Improvement Plan**	**Implementation**		
			Implemented	**Acceptable**	**Unacceptable**
Environmental	1	Promote the LPG conversion programme	√		
	2	Support research and development for sustainable fishing vessel design		√	
	3	Promote the fibreglass conversion programme	√		
	4	Implement the seasonal fishing ban			√
	5	Fish stock assessment for Palabuhanratu Bay	√		
	6	Propose management action which consider economic and social impacts		√	
	7	Encourage the seller to be involved in improving fisher's wealth			√
	8	Maintain fish prices	√		
	9	Activate a proper auction mechanism			√
	10	Develop renewable energy for Small Medium Enterprises (SMEs)			√
	11	Develop a greener method for existing electricity production			√
	12	Support research and development of the environmentally friendly paint and anti-fouling			√
Economic	13	Amend the law on the fisheries sharing system		√	
	14	Maintain the fuel price			√
Social	15	Monitor the implementation of mandatory education			√
	16	Protect the street children			√
	17	Conduct safety workshops		√	
	18	Ensure the availability of safety equipment on the fishing vessels		√	
	19	Improve accident handling		√	
	20	Disseminate the insurance programme and monitor its implementation	√		

6.8 Implementation strategies

Following the formulation of best practice, the strategies to implement those achievable measures are explained as follows. Table 6.13 shows that, generally, at the practical level, the fishing operations have been conducted to incorporate best practice, regardless of several limited applications.

In order to improve sustainability performance, initial focus should be on the acceptable measures. Furthermore, research and dissemination are required to encourage the realisation of those measures. This emphasises that academics and researchers should be involved in the sustainable development of SSFV operations by focusing their work on the acceptable measures.

Subsequently, the fishing community should be encouraged to maintain and improve the existing practices, particularly the measures which are partially implemented, for example, increasing their awareness of the ecosystem quality and on vessel protection from mechanical damage. Regarding ecosystem awareness, the main issue is the fisher's behaviour which disregards the size of the fish. To overcome this problem, education is required to increase the attention, which addresses not only the fishers as the fish hunter but also the owner and the seller as part of the value chain actors. Furthermore, the monitoring system should be improved by the fishing inspectors who are based in the port. Concerning the protection of the vessels, fishers should be informed of the effectiveness of installing fenders, which should be identified based on a comprehensive study.

Unacceptable measures do not necessarily refer to impossible solutions. Instead, this indicates that in order to implement that solution, greater effort and consideration are required, as the fishing community is reluctant to accept. It is important to note that the attempt made regarding the implementation and benefits achieved from it should be balanced.

Similar to the practical level, in order to improve sustainable development in the fisheries sector, the government should first execute the acceptable measures either by strengthening the existing regulation, improving the supervision programme for the fishing community or issuing a new policy. Not all fisheries policy should be centrally produced by the MMAF, as the local fisheries council also has the authority to produce local guidelines. This can be specifically designed for the local community and deliver greater benefits. For example, the local council can propose action to legalise the sharing system for different types of fishing operations conducted in the region. Even though the fishing community claimed that the current share is fair, this regulation will protect their bargaining position. Furthermore, despite working under different management, both the local fisheries council and the fishing port authority should improve their collaboration.

Secondly, the existing programmes should be properly maintained and enhanced, with the focus on the partially implemented measures. Furthermore, although the number of unacceptable measures listed in Table 6.14 is higher than the implemented and acceptable measures, it does not mean that the current fisheries management cannot be performed at its best. This is because sustainable development at the policy level is not merely the responsibility of fisheries-related institutions. This fact suggests that collaboration inter institutions both at the regional or national level is also essential in developing sustainable fishing vessel operations.

6.9 Summary

Following the sustainability performance described in Chapter 5, this chapter discusses areas for potential improvement, the possible and achievable measures, as well as the strategies for implementation.

A number of areas for potential improvement have been identified regarding to environmental, economic and social performance constituting 12, 9 and 4 areas respectively. During the identification process, it was revealed that not every single indicator with a significant negative impact is relevant to each studied vessel, for example, fuel consumption in the LF vessels. Therefore, the formulation of possible measures is focused on the indicator which requires further improvement. In order to provide comprehensive measures, practical and policy perspectives are used representing both the fishing community and the government. As a result, 30 measures are proposed at the practical level, whilst 20 measures are recommended at the policy level.

Through the FGD and interviews, members of the fishing community and government representatives are asked to justify the degree of implementation of the proposed measures into three categories, specifically implemented, acceptable and unacceptable. The first two categories are referred as the best practice. It is revealed by its number, that

23 proposed measures at the practical level were identified as best practice, and 18 of them have been implemented. Therefore, it is argued that at the practical level, the fishing operations have been conducted responsibly. At the policy level, 11 out of 20 proposed measures are considered as best practice, yet only 5 of them are implemented. Some proposed measures are beyond the authority of fisheries-related organisations, thus, collaboration with other institutions is required in order to develop sustainable fishing vessel operations. For further improvement in both levels, actions should be concerned on the best practice which has not been implemented.

At this point, the research questions have been addressed with three deliverables, i.e. sustainability status, possible measures and best practice. In the subsequent chapter, the discussion focuses on suitability of the method applied in this study to address the existing problems and the implementation in a broader context.

Chapter 7. Discussion and Conclusion

7.1 Introduction

In Chapters 5 and 6, two research questions have been addressed by means of three deliverables, i.e. sustainability performance, possible measures to improve the sustainability performance and best practice formulation. Subsequently, this chapter will present a general discussion of the study, recommendations for future work, the contribution toward the existing knowledge, and the conclusion.

7.2 Thesis summary

The main idea of this research is developing sustainable SSFV operations, which was conducted by using a case study in Palabuhanratu, Indonesia. The background information concerning this research, including the motivation and general methodology, has been described in Chapter 1. To align with current knowledge, Chapter 2 provides the literature review concentrating on the theoretical context of the study.

The study of the sustainable development of SSFV operations consists of four major parts, namely understanding the current practice, impact assessment, identification of possible measures, and the formulation of best practice. A description of the current fishing practices is given in Chapters 3 and 4. Whilst Chapter 3 pictures the situation at global, national and local levels, Chapter 4 models the existing fishing operations at the research site and defines input variables for further calculation. This model enables this research to estimate the profit received by different stakeholders, investment and maintenance costs and long-term financial analysis.

Having developed an understanding of the current situation, Chapter 5 describes the performance of SSFV operations, which is assessed using three indicators of sustainability, i.e. environmental, economic and social aspects. Environmental performance is assessed by means of energy consumption, CO_2 emissions and LCA. Economic performance is measured by way of annual profit, LCC and financial analysis and finally, social performance is assessed using S-LCA with a framework which was adapted from the UNEP.

Chapter 6 discusses the final two parts of the sustainable development of SSFV operations. Firstly, possible measures to improve the current performance are identified by mapping the areas for potential improvement based on the assessment result and literature review. Subsequently, best practice and implementation strategies are formulated by involving the stakeholders.

Accordingly, the general discussion in this section will incorporate: the relevance of this research to the SDGs proposed by the UN; suitability of the applied method to answer the existing problems; opportunities and challenges attached to the existing fishing practices; and the potential implementation at different levels of fishing operations.

7.3 Commitment to achieve Sustainable Development Goals

As one of the member states of the UN, Indonesia has voluntary commitments to delivering 2030 SDGs agenda. Several are fishery-related actions which focus on Goal 14 such as performing climate education for fishers; combatting human rights exploitations in the fishing industry; forming coral triangle initiatives on coral reefs, fisheries and food security with neighbouring countries; fighting illegal, unreported, and unregulated fishing; and establishing marine protected areas. Further details pertaining to those commitments can be seen in the partnerships & commitments of the Indonesian government (UN, 2018). Furthermore, in order to increase the competitiveness of Indonesian fisheries in the international market the government has encouraged national fishing practices to obtain a sustainability certification. To date, a tuna fishery company in Papua has become the first fishery in Indonesia and the second in Southeast Asia to be certified by Marine Stewardship Council (MSC), an international organisation which set standard for sustainable fishing (MSC, 2018). This fact suggests that implementing the sustainable development of SSFV operations at the policy level will improve Indonesia’s dedication in conserving and utilising the oceans and marine resources in sustainable ways.

In order to achieve the goals, each country might have different priorities and targets. The summary of the commitment and partnership of the UN member states is presented as follow (UN, 2018). Compared to other neighbouring countries such as Vietnam, Myanmar and the Philippines, Indonesia engages in more fishery-related programmes. This indicates that as an archipelagic state and major fish producer in the global market, Indonesia has more responsibilities on the development of sustainable fisheries and the protection of marine environment. Given that fishery management involve transboundary resources, Indonesia also participates in the regional partnership with Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste to sustain marine and coastal resources. Comparison with other major fish producers such as China, Japan and USA reveals that those countries participate in the promotion of sustainable fisheries in other countries through an international partnership in the form of technology transfer, strategic expertise or financial assistant, whilst most programmes committed by Indonesian government focus at the national level. Furthermore, under the International Hydrographic Organisation (IHO), Indonesia with other 86 countries involve in the capacity building programme for coastal states. Whilst developing countries focus on the optimising economic benefit from marine utilisation, developed countries show more concerns on the development of science and technology which support the decision making process in managing sustainable fisheries through data advancement and innovation.

7.4 Methodological review

In this research, the development of sustainable SSFV operations is approached using the system engineering (SE) process. As depicted in Figure 1.4, the procedure consists of several steps which correspond to six significant steps of the SE process. The primary user of the proposed system is the fishing community and the government. Two different solutions produced in practical and policy measures represent the viewpoints of two stakeholders. This mechanism allows them to be involved in the formulation of best practice. Besides, the identification of areas for potential improvement enables the study to propose implementation strategies, which are expected to achieve the optimum improvement result.

Referring to the research questions, the application of the SE process is capable of addressing the problems by mapping the performance of the current SSFV operations and proposing the best practice for an improvement plan. In the future, the assessment result from this research can be used to measure the effectiveness of the action plans or to benchmark the performance of other fishing operations. Furthermore, incorporating the assessment into three pillars of sustainability offers a comprehensive evaluation, which is in line with the principle of sustainable development.

However, it is undeniable that there are certain limitations regarding the implementation of the SE process by incorporating the pillars of sustainability. Firstly, it is time-consuming due to the broad scope of the analysis, thus a clear boundary is a necessity in order to deliver the expected outcome. Time limitation also leads to generalisation and simplification, which might neglect some essential details. Secondly, it requires sufficient data which is not only collected on-site (primary data) but also published data gathered by other parties (secondary data). Regarding the secondary data, not all data is relevant to the investigated area. Hence, some omission is inevitable, which could cause bias in the result. An example is the use of the background data for the LCA, which mostly comprises European or worldwide data. This situation suggests providing clear calculation procedures which allow other scholars to trace the calculation process. Thirdly, no standard is agreed to define the relevant sustainability status of the fishing vessel operation. It is therefore recommended that a comparative study be carried out in order to perform a fair assessment, which would increase the complexity of the assessment.

The sustainability analysis of the fishery system focuses on the natural ecosystem and the human system, which consists of ecological, socio-economic, community, and institutional sustainability (Charles, 2001). Each component has individual indicators representing fishing practice. According to Figure 2.1, fishing operations are part of the human system, therefore, the development of sustainable SSFV will support the promotion of socio-economic sustainability. Given the inclusion of energy consumption and life cycle assessment of the fishing vessels, this research also contributes to the promotion of ecological sustainability. It is argued, therefore, that the development of sustainable SSFV operations remains relevant to the general concept of sustainable fisheries. Furthermore, as confirmed by Utne (2007), integrating the technical perspective into sustainable fisheries management will enhance the existing decision-making methods.

For the last four years, the development of sustainable fisheries in Indonesia has been focused on three programmes, i.e. combating IUU fishing, conserving marine resources and improving the prosperity of the fishing community (MMAF, 2017c). Furthermore, the government has committed to implementing responsible fisheries in accordance with the Code of Conduct for Responsible Fisheries (the Code). Accordingly, the development of sustainable SSFV operations will support that commitment if fishing vessel operations are seen as the dominant process in the marine fisheries system.

7.5 Opportunities and challenges for the sustainable development of SSFV operations in Palabuhanratu

As one of the major economic sectors in Palabuhanratu, it is important that the fisheries sector should be developed sustainably. Besides, the existing infrastructure enable fishing activities to be accommodated on a long-term basis and at different business scales. According to the description of the existing fishing operations and its performance, some opportunities which have the potential to encourage the promotion of sustainable SSFV operations in Palabuhanratu are explained below.

1. Protected by the state

   According to the Code, which is further detailed in the FAO voluntary guidelines for securing sustainable small-scale fisheries (FAO, 2015c), nation states should acknowledge the contribution, and protect the existence of, small-scale fisheries. At the national level, the government has demonstrated its commitment by issuing specific regulations which stress the protection of small-scale fisheries. This means that any SSFV operated in Palabuhanratu is legally protected, if it is conducted responsibly.

2. Good infrastructure

   Palabuhanratu fishing port has adequate infrastructure to accommodate various fishing-related business, such as cold storage, an ice plant, docking facilities and fuel stations. Furthermore, there is also access to regional, national and global fish markets.

3. Local culture

   Most fishers and value chain actors associated with SSFV operations are residents of Palabuhanratu. Members of the fishing community value fisheries as part of their identity. Besides, residents from non-fishing communities appreciate it as part of the local culture. A study conducted by Holen (2014), shows that the sustainability of the fishing practice depends on the community's ability to adapt to fishing opportunities and their appreciation of fisheries. This means that the strong culture will encourage the residents to continue fishing activities as part of their identity.

4. Potential market

   Palabuhanratu is located in the national park area known as Geopark Ciletuh, which has 128 ha of land spreading over eight districts and 74 villages. The park consists of some popular destinations including Palabuhanratu beach. In 2017, the UNESCO acknowledged the park as part of the Global Geopark Network (Ministry of Tourism, 2018). This status is expected to attract more tourists, both national and international, to visit the region, which means increasing the potential market for seafood products and recreational fishing.

5. Eradication of illegal, unreported and unregulated (IUU) fishing

   It is claimed that the eradication of IUU fishing in Indonesia has increased the fish stock from 9.93 million tons per year in 2015 to 12.54 million per year in 2017, which presents local fishers to better fishing opportunities. To meet this challenge, the government supports local fishers with improved infrastructure through fishing vessel grants, fishing port development and enhancement of the seafood product supply chain. These national programmes are partially implemented in Palabuhanratu.

However, there are also several challenges, which obstruct the development of sustainable SSFV operations.

1. Fisher's limited skills

   Most fishers are only skilled at the fishing operations they usually perform. Hence, asking them to conduct different operations which are more sustainable is challenging, as it conflicts with their habitual practices and skills. Furthermore, the interest of young people in small-scale fisheries is decreasing and consequently, impedes the regeneration of the fishers' community in this sector.

2. Limited fishing capacity.

   Even though the region is facing the ocean, the local fishers only conduct small-scale fisheries using vessels up to 5 GT or less. The fishing is limited to waters close to the shore, because the centre of the bay has a depth of more than 2000 metres (Dishidros, 2004). The proximity to the Indian Ocean offers an opportunity to develop the fishing industry, not only in scale but also in the fishing methods. Native fishers have no interest in conducting larger scale operations due to limitations in fishing capital and skills. Despite the fact that numerous competent young people are produced by the local vocational school, most are more interested in working on foreign fleets than in the national fleet.

3. Restricted financial institutions

   The financial issue is becoming a significant problem as it means most fishers or owners are bonded with debt and forced to collaborate with the seller in order to continue their operations. The fishers and owners need a loan with low interest, a simple mechanism, which is accessible at any time. This can only be provided by the seller, as the personal creditor, as no formal financial institution is suitable for that. Even though certain banks provide support by offering soft loans, the fishers are hampered by the issue of a guarantee, as not every fishing vessel can be used as collateral.

4. The threat of overfishing and marine pollution

   It is undeniable that the sustainability of the fishing vessel operations is extremely dependent on the sustainability of marine resources. Therefore, responsible fishing practices should be conducted in order to prevent depletion of the fish stock.

   Furthermore, pollution from industries and vessels operations affects the quality of the marine ecosystem, which also affects the abundance of fish. Approximately 7 km from the fishing port, a steam power plant has been established and has been operating since December 2012. This plant has a private jetty, which cause beach siltation in the closest fishing grounds, Furthermore, the plant requires a regular supply of coal by sea, which has the potential to produce more pollutant. According to Indonesia Power (2017), a waste bank has been established as part of their corporate social responsibility programme which mainly focuses on SDGs 3 (good health and well-being), 8 (decent work and economic growth) and 11 (sustainable cities and communities). The omission of SGDs 13 and 14 indicates that less attention is paid to the sustainability of marine life as sources of livelihood for the surrounding community.

7.6 Future work

7.6.1 Implementation in other small-scale fishing vessel operations

This research has successfully assessed sustainability performance and proposed various recommendations to improve the existing practices. However, the study has been conducted with some limitations, therefore there are several recommendations for enhancement of the method for any further research.

Firstly, the assessment framework can be developed by including additional environmental indicators, such as bycatch and fishing gear performance. Adding those two indicators would allow the assessment to consider the performance of the fishing vessel in exploiting the fish resources. Secondly, the performance score was produced using a simple aggregation method. Another enhancement would be to develop a calculation technique that apply different weighting factors based on the importance level of each indicator.

7.6.2 Implementation in the large-scale fishing vessel operations

Large-scale fishing vessel (LSFV) operations are mostly associated with commercial fishing activities, although no universal definition is agreed. The sustainable development method used in this research is not explicitly developed for the SSFV. Hence, no substantial issue will restrict its implementation in the LSFV operation. However, the characteristics of LSFV (see Table 2.1), have some dissimilarities which affect the variable of assessment of variables, as detailed in the following examples.

1. Larger vessels require more fishing inputs, not only in quantity but also in the type. For example, fish storage in the larger vessel is typically designed below the deck using either insulated or refrigerated compartments, which affects the LCA inventory.

2. The structure of the value chain actors in the LSFV is more complicated than the SSFV, as it involves a wider range of stakeholders. For example, a cold storage and

transhipment service might be included in the chain relating to the seafood production system.

3. An LSFV is typically owned by a company, which has a formally structured operational management system including a fishing logbook, a recruitment system and a payment scheme. Collecting data from the company will be challenging due to the data privacy issue and commercial confidentiality.

4. LSFV operations are conducted offshore, nonetheless its enormous fishing capacity could affect fish stocks in the coastal area. Thus, a potential conflict with SSFV operations should be considered in the social impact assessment.

5. The catch from LSFV can be landed at a different port from where the vessel departed. Furthermore, the fishers on LSFV can be recruited from various places. These facts explain that the LSFV operation not only deals with various local communities but also with a range of fishers' backgrounds.

7.6.3 Implementation in the regional and national context

The investigation was conducted on four fishing operations which characterise typical practices in the region. Furthermore, sustainability performance was evaluated based on the assessment result from four representative vessels. The assessment was designed to produce a comprehensive investigation and attention was given as to how each fishing vessel can improve its existing performance.

Development of sustainable fishing vessel operations at the regional and national level involves a broader scope and greater resources. Investigation of a single vessel will be of limited, so it is suggested that an assessment is conducted on a fleet basis. In order to produce specific management measures, classification could be based on variety of grouping methods, such as fishing gear, fish target, vessel size or fishing ground.

Given the scope of analysis has to be broadened by using multi-vessel analysis, the assessment framework should be modified, as not all indicators used in this study will be applicable, one example financial analysis. It could be adjusted according to the data and availability of resources (Utne, 2008). Therefore, for general application, Figure 7.1 shows the suggested flowchart to develop sustainable fishing vessel operations. Data inputs and indicators might vary, depending on the scope of the analysis. Stakeholders can be involved during the data collection and sustainability assessment, however, the

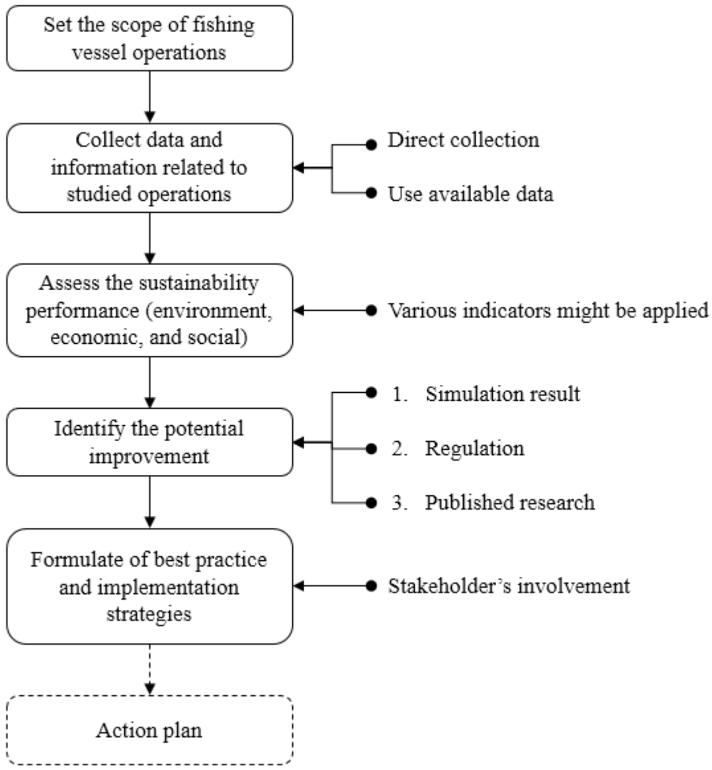


Figure 7.1 General procedure for developing sustainable fishing vessel operations

most significant part is during the formulation of best practice, for the reason that it affects the effectiveness of the following action plan.

At the national level, data collection will mostly rely on statistics due to the extensive coverage. Therefore, it is suggested that three indicators are used in the assessment, i.e. fuel use intensity (FUI), profitability, and employment. Given that fuel consumption is the major contributor to the environmental impact, FUI will be a representative indicator. Furthermore, the economic impact of the activity is evaluated based on the owner's and fisher's profit because it enables the assessment to show the impact for individuals. For Indonesian context, fisher's terms of trade can be used as an alternative economic indicator, since it is published by both regional and central government on a regular basis. However, it should be noted that the FUI must be calculated from the same data sources in order to provide a related result that can be used for comparative purposes. Finally, social impact is specified by employment which can be represented by a fair salary, as well as health and safety, which are crucial issues in the fisher's wellbeing.

Alternatively, a life cycle approach can be used in the sustainability assessment by combining LCA, LCC and S-LCA. Although it will be more challenging for a multi-vessel assessment, it does provide a comprehensive assessment that is in line with the principle of sustainable development. In addition, this method results in valuable information which supports the decision-making process at both regional and national levels.

7.6.4 Implementation in the global context

Since Figure 7.1 is intended for general application, it is plausible to assume that the procedure is also applicable both for developed and developing countries. However, the scope of assessment, indicators, assessment method and the type of stakeholders involved in the process might be different. This is because each country has a unique characteristic regarding fisheries policy and management, which affect the profile of the fishing vessel operations and the access to data.

Application in the developing countries might use the same indicators as suggested for the Indonesian context. However, the developed countries indicators might be broadened to include different types of emissions, accident rates and the possession of eco-labelling certification. Furthermore, for an assessment using a life cycle approach, such as LCA, in a developed country might prove to be more accurate, as most of the available databases are relevant to the system. This fact suggests that when conducting a comparative study between developed and developing countries, the challenge will be to present an equal comparison, seeing as the fishing vessel operation might have a completely different background.

7.7 Original contribution to knowledge

In Chapter 2, it was explained that there is a challenge with respect to promoting sustainable fisheries through the development of sustainable fishing vessel operations. The investigation focuses on the impacts derived from the operation of fishing vessels, and on improvement strategies, and it is expected to enrich the existing management measures, which are primarily based on the fish stock and fishing gear. Accordingly, this thesis contributes by adding to existing knowledge and understanding in the following ways.

Firstly, regarding the fishing sector, this research introduces sustainability assessment of the SSFV operations and incorporates the three elements of sustainability. Similar research was undertaken by (Utne (2007)), yet this study used different indicators, which were mainly approached via the life cycle concept. The investigation has focused only on four vessels representing active-passive fishing and demersal-pelagic fishing, which allow direct comparison between the vessels. The application of the SE process has resulted in management measures (Table 6.13 and 6.14), which are based on both fishing community and government perspectives.

Secondly, concerning the knowledge of sustainable assessment procedures, this research employed a range of impact assessment methods developed separately by other researchers, either in fishery-related areas or beyond. Those methods have been combined to form a specific framework, which is applied to investigate the sustainability of fishing vessel operations.

7.8 Conclusion

This research investigates the sustainable development of SSFV operations based in Palabuhanratu fishing port. The investigation has been focused on four types of fishing vessels operated around Palabuhanratu Bay i.e. pelagic Danish seiner (PD vessel) representing active and pelagic fishing, trammel netter (TN vessel) denoting active and demersal fishing, handliner (HL vessel) signifying passive and demersal fishing and lift netter (LF vessel) representing passive and pelagic fishing. Fishing operations fluctuate seasonally following the weather and fish abundance. Hence, models have been developed in order to illustrate the current fishing practices of each studied vessel throughout the year. The models generate annual data which has been used for a sustainability assessment.

The assessment result reveals that in terms of environmental and economic performance, passive operations conducted by HL and LF vessels are more sustainable than active operations performed by PD and TN vessels. Furthermore, the result variation in each vessel is not enough to justify that pelagic fishing is more sustainable than demersal fishing or vice versa. Regarding social performance, the assessment was carried out by merging the fishing community of the four studied vessels, and as a consequence, it resulted in a single performance score. Accordingly, amongst the four studied vessels, no single operation performs well in all sustainability elements, which indicates the importance of a trade-off between environmental, economic and social aspects when encouraging sustainable development.

In order to improve sustainability performance with respect to environmental, economic and social performance, 12, 9 and 4 areas respectively have been identified for potential improvement. Accordingly, a range of possible measures, which comprise 30 measures at the practical level and 20 measures at the policy level, which can be seen in Table 6.13 and 6.14, are proposed to the stakeholders.

Through focused group discussion, 23 measures are identified as the best practice for the practical level. It is argued that fishing operations have been conducted optimally, given that 18 out of 23 measures have already been implemented. At the policy level, best practice consists of 11 measures, 5 of which have already been implemented. Although it is evident that more measures need to be implemented does not indicate that that the government does not make optimal efforts, because some of the proposed measures are actually beyond the authority of the fisheries-related organisations. For further improvement at both levels, actions should be focused on best practice which has not been as yet implemented. Specifically, at the policy level, collaboration with other government institutions is also required in order to promote sustainable SSFV operations.

Regarding the hypothesis, this research has demonstrated that the sustainable development of SSFV operations can be approached by using the SE process combining environmental, economic and social aspects. This method enables the performance of fishing vessel operations to be investigated comprehensively. The outcome of this research will help the decision makers with effective management measures to support the development of responsible fisheries.

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Appendix A. The classification of fishing gear and fishing vessel

International Standard Statistical Classification of Fishing Gear (ISSCFG)
(29 July 1980)

Gear Categories Abbreviation Code	Standard Abbreviations	ISSCFG
SURROUNDING NETS		01.0.0
With purse lines (purse seines)	PS	01.1.0
- one boat operated purse seines	PS1	01.1.1
- two boats operated purse seines	PS2	01.1.2
Without purse lines (lampara)	LA	01.2.0
SEINE NETS		02.0.0
Beach seines	SB	02.1.0
- boat or vessel seines	SV	02.2.0
- Danish seines	SDN	02.2.1
- Scottish seines	SSC	02.2.2
- pair seines	SPR	02.2.3
Seine nets (not specified)	SX	02.9.0
TRAWLS		03.0.0
Bottom trawls		03.1.0
- beam trawls	TBB	03.1.1
- otter trawls[1]	OTB	03.1.2
- pair trawls	PTB	03.1.3
- nephrops trawls	TBN	03.1.4
- shrimp trawls	TBS	03.1.5
- bottom trawls (not specified)	TB	03.1.9
Midwater trawls		03.2.0
- otter trawls[1]	OTM	03.2.1
- pair trawls	PTM	03.2.2
- shrimp trawls	TMS	03.2.3
- midwater trawls (not specified)	TM	03.2.9
Otter twin trawls	OTT	03.3.0
Otter trawls (not specified)	OT	03.4.9
Pair trawls (not specified)	PT	03.5.9
Other trawls (not specified)	TX	03.9.0
DREDGES		04.0.0
Boat dredges	DRB	04.1.0
Hand dredges	DRH	04.2.0

[1] Fisheries agencies may indicate side and stern bottom, and side and stern midwater trawls, as OTB-1 and OTB-2, and OTM-1 and OTM-2, respectively.

International Standard Statistical Classification of Fishing Gear (ISSCFG)
(29 July 1980) (cont'd)

Gear Categories Abbreviation Code	Standard Abbreviations	ISSCFG
LIFT NETS		05.0.0
Portable lift nets	LNP	05.1.0
Boat-operated lift nets	LNB	05.2.0
Shore-operated stationary lift nets	LNS	05.3.0
Lift nets (not specified)	LN	05.9.0
FALLING GEAR		06.0.0
Cast nets	FCN	06.1.0
Falling gear (not specified)	FG	06.9.0
GILLNETS AND ENTANGLING NETS		07.0.0
Set gillnets (anchored)	GNS	07.1.0
Driftnets	GND	07.2.0
Encircling gillnets	GNC	07.3.0
Fixed gillnets (on stakes)	GNF	07.4.0
Trammel nets	GTR	07.5.0
Combined gillnets-trammel nets	GTN	07.6.0
Gillnets and entangling nets (not specified)	GEN	07.9.0
Gillnets (not specified)	GN	07.9.1
TRAPS		08.0.0
Stationary uncovered pound nets	FPN	08.1.0
Pots	FPO	08.2.0
Fyke nets	FYK	08.3.0
Stow nets	FSN	08.4.0
Barriers, fences, weirs, etc	FWR	08.5.0
Aerial traps	FAR	08.6.0
Traps (not specified)	FIX	08.9.0
HOOKS AND LINES		09.0.0
Handlines and pole-lines (hand operated)[1]	LHP	09.1.0
Handlines and pole-lines (mechanized)[1]	LHM	09.2.0
Set longlines	LLS	09.3.0
Drifting longlines	LLD	09.4.0
Longlines (not specified)	LL	09.5.0
Trolling lines	LTL	09.6.0
Hooks and lines (not specified)[2]	LX	09.9.0

[1] Including jigging lines
[2] Code LDV for dory-operated line gears will be maintained for historical data purposes

International Standard Statistical Classification of Fishing Gear (ISSCFG)
(29 July 1980) (concluded)

Gear Categories Abbreviation Code	Standard Abbreviations	ISSCFG
GRAPPLING AND WOUNDING		10.0.0
Harpoons	HAR	10.1.0
HARVESTING MACHINES		11.0.0
Pumps	HMP	11.1.0
Mechanized dredges	HMD	11.2.0
Harvesting machines (not specified)	HMX	11.9.0
MISCELLANEOUS GEAR[1]	MIS	20.0.0
RECREATIONAL FISHING GEAR	RG	25.0.0
GEAR NOT KNOWN OR NOT SPECIFIED	NK	99.0.0

[1] This item includes: hand and landing nets, drive-in-nets, gathering by hand with simple hand implements with or without diving equipment, poisons and explosives, trained animals, electrical fishing.

INTERNATIONAL STANDARD STATISTICAL CLASSIFICATION OF FISHERY VESSELS (ISSCFV) BY VESSEL TYPES

Vessel Categories	Standard Abbreviation	ISSCFV Code
FISHING VESSELS		
TRAWLERS	TO	01.0.0
Side trawlers	TS	01.1.0
wet-fish	TSW	01.1.1
freezer	TSF	01.1.2
Stern trawlers	TT	01.2.0
wet-fish	TTW	01.2.1
freezer	TTF	01.2.2
factory	TTP	01.2.3
Outrigger trawlers	TU	01.3.0
Trawler nei	TOX	01.9.0
SEINERS	SO	02.0.0
Purse seiners	SP	02.1.0
- North American type	SPA	02.1.1
- European type	SPE	02.1.2
Tuna purse seiners	SPT	02.1.3
Seine netters	SN	02.2.0
Seiner nei	SOX	02.9.0
DREDGERS	DO	03.0.0
using boat dredge	DB	03.1.0
using mechanical dredge	DM	03.2.0
dredgers nei	DOX	03.9.0
LIFT NETTERS	NO	04.0.0
using boat operated net	NB	04.1.0
lift netters nei	NOX	04.9.0
GILLNETTERS	GO	05.0.0
TRAP SETTERS	WO	06.0.0
Pot vessels	WOP	06.1.0
Trap setters nei	WOX	06.9.0

Note: nei is the abbreviation for the phrase "not elsewhere identified"

International Standard Statistical Classification of Fishery Vessels (ISSCFV) by Vessel Types (concluded)

Vessel Categories	Standard Abbreviation	ISSCFV Code
LINERS	LO	07.0.0
Handliners	LH	07.1.0
Longliners	LL	07.2.0
Tuna longliners	LLT	07.2.1
Pole and line vessels	LP	07.3.0
Japanese type	LPJ	07.3.1
American type	LPA	07.3.2
Trollers	LT	07.4.0
Liners nei	LOX	07.9.0
VESSELS USING PUMPS FOR FISHING	PO	08.0.0
MULTIPURPOSE VESSELS	MO	09.0.0
Seiner-handliners	MSN	09.1.0
Trawler-purse seiners	MTS	09.2.0
Trawler-drifters	MTG	09.3.0
Multipurpose vessels nei	MOX	09.9.0
RECREATIONAL FISHING VESSELS	RO	10.0.0
FISHING VESSELS NOT SPECIFIED	FX	49.0.0
NON-FISHING VESSELS		
MOTHERSHIPS	HO	11.0.0
Salted-fish motherships	HSS	11.1.0
Factory motherships	HSF	11.2.0
Tuna motherships	HST	11.3.0
Motherships for two-boat purse seining	HSP	11.4.0
Motherships nei	HOX	11.9.0
FISH CARRIERS	FO	12.0.0
HOSPITAL SHIPS	KO	13.0.0
PROTECTION AND SURVEY VESSELS	BO	14.0.0
FISHERY RESEARCH VESSELS	ZO	15.0.0
FISHERY TRAINING VESSELS	CO	16.0.0
NON-FISHING VESSELS nei	VOX	99.0.0

Note: nei is the abbreviation for the phrase "not elsewhere identified"

Appendix B. Code of conduct of responsible fisheries (Article 8)

ARTICLE 8 - FISHING OPERATIONS

8.1 Duties of all States

8.1.1 States should ensure that only fishing operations allowed by them are conducted within waters under their jurisdiction and that these operations are carried out in a responsible manner.

8.1.2 States should maintain a record, updated at regular intervals, on all authorizations to fish issued by them.

8.1.3 States should maintain, in accordance with recognized international standards and practices, statistical data, updated at regular intervals, on all fishing operations allowed by tem.

8.1.4 States should, in accordance with international law, within the framework of subregional or regional fisheries management organizations or arrangements, cooperate to establish systems for monitoring, control, surveillance and enforcement of applicable measures with respect to fishing operations and related activities in waters outside their national jurisdiction.

8.1.5 States should ensure that health and safety standards are adopted for everyone employed in fishing operations. Such standards should be not less than the minimum requirements of relevant international agreements on conditions of work and service.

8.1.6 States should make arrangements individually, together with other States or with the appropriate international organization to integrate fishing operations into maritime search and rescue systems.

8.1.7 States should enhance through education and training programmes the education and skills of fishers and, where appropriate, their professional qualifications. Such programmes should take into account agreed international standards and guidelines.

8.1.8 States should, as appropriate, maintain records of fishers which should, whenever possible, contain information on their service and qualifications, including certificates of competency, in accordance with their national laws.

8.1.9 States should ensure that measures applicable in respect of masters and other officers charged with an offence relating to the operation of fishing vessels should include provisions which may permit, *inter alia,* refusal, withdrawal or suspension of authorizations to serve as masters or officers of a fishing vessel.

8.1.10 States, with the assistance of relevant international organizations, should endeavour to ensure through education and training that all those engaged in fishing operations be given information on the most important provisions of this Code, as well as provisions of relevant international conventions and applicable environmental and other standards that are essential to ensure responsible fishing operations.

8.2 Flag State duties

8.2.1 Flag States should maintain records of fishing vessels entitled to fly their flag and authorized to be used for fishing and should indicate in such records details of the vessels, their ownership and authorization to fish.

8.2.2 Flag States should ensure that no fishing vessels entitled to fly their flag fish on the high seas or in waters under the jurisdiction of other States unless such vessels have been issued with a Certificate of Registry and have been authorized to fish by the competent authorities. Such vessels should carry on board the Certificate of Registry and their authorization to fish.

8.2.3 Fishing vessels authorized to fish on the high seas or in waters under the jurisdiction of a State other than the flag State, should be marked in accordance with uniform and internationally recognizable vessel marking systems such as the FAO Standard Specifications and Guidelines for Marking and Identification of Fishing Vessels.

8.2.4 Fishing gear should be marked in accordance with national legislation in order, that the owner of the gear can be identified. Gear marking requirements should take into account uniform and internationally recognizable gear marking systems.

8.2.5 Flag States should ensure compliance with appropriate safety requirements for fishing vessels and fishers in accordance with international conventions, internationally agreed codes of practice and voluntary guidelines. States should adopt appropriate safety requirements for all small vessels not covered by such international conventions, codes of practice or voluntary guidelines.

8.2.6 States not party to the Agreement to Promote Compliance with International Conservation and Management Measures by Vessels Fishing in the High Seas should be encouraged to accept the Agreement and to adopt laws and regulations consistent with the provisions of the Agreement.

8.2.7 Flag States should take enforcement measures in respect of fishing vessels entitled to fly their flag which have been found by them to have contravened applicable conservation and management measures, including, where appropriate, making the contravention of such measures an offence under national legislation. Sanctions applicable in respect of violations should be adequate in severity to be effective in securing compliance and to discourage violations wherever they occur and should deprive offenders of the benefits accruing from their illegal activities. Such sanctions may, for serious violations, include provisions for the refusal, withdrawal or suspension of the authorization to fish.

8.2.8 Flag States should promote access to insurance coverage by owners and charterers of fishing vessels. Owners or charterers of fishing vessels should carry sufficient insurance cover to protect the crew of such vessels and their interests, to indemnify third parties against loss or damage and to protect their own interests.

8.2.9 Flag States should ensure that crew members are entitled to repatriation, taking account of the principles laid down in the "Repatriation of Seafarers Convention (Revised), 1987, (No.166)".

8.2.10 In the event of an accident to a fishing vessel or persons on board a fishing vessel, the flag State of the fishing vessel concerned should provide details of the accident to the State of any foreign national on board the vessel involved in the accident. Such information should also, where practicable, be communicated to the International Maritime Organization.

8.3 Port State duties

8.3.1 Port States should take, through procedures established in their national legislation, in accordance with international law, including applicable international agreements or arrangements, such measures as are necessary to achieve and to assist other States in achieving the objectives of this Code, and should make known to other States details of regulations and measures they have established for this purpose. When taking such measures a port State should not discriminate in form or in fact against the vessels of any other State.

8.3.2 Port States should provide such assistance to flag States as is appropriate, in accordance with the national laws of the port State and international law, when a fishing vessel is voluntarily in a port or at an offshore terminal of the port State and the flag State of the vessel requests the port State for assistance in respect of non-compliance with subregional, regional or global conservation and management measures or with internationally agreed minimum standards for the prevention, of pollution and for safety, health and conditions of work on board fishing vessels.

8.4 Fishing operations

8.4.1 States should ensure that fishing is conducted with due regard to the safety of human life and the International Maritime Organization International Regulations for Preventing Collisions at Sea, as well as International Maritime Organization requirements relating to the organization of marine traffic, protection of the marine environment and the prevention of damage to or loss of fishing gear.

8.4.2 States should prohibit dynamiting, poisoning and other comparable destructive fishing practices.

8.4.3 States should make every effort to ensure that documentation with regard to fishing operations, retained catch of fish and non-fish species and, as regards discards, the information required for stock assessment as decided by relevant management bodies, is collected and forwarded systematically to those bodies. States should, as far as possible, establish programmes, such as observer and inspection schemes, in order to promote compliance with applicable measures.

8.4.4 States should promote the adoption of appropriate technology, taking into account economic conditions, for the best use and care of the retained catch.

8.4.5 States, with relevant groups from industry, should encourage the development and implementation of technologies and operational methods that reduce discards. The use of fishing gear and practices that lead to the discarding of catch should be discouraged and the use of fishing gear and practices that increase survival rates of escaping fish should be promoted.

8.4.6 States should cooperate to develop and apply technologies, materials and operational methods that minimize the loss of fishing gear and the ghost fishing effects of lost or abandoned fishing gear.

8.4.7 States should ensure that assessments of the implications of habitat disturbance are carried out prior to the introduction on a commercial scale of new fishing gear, methods and operations to an area.

8.4.8 Research on the environmental and social impacts of fishing gear and, in particular, on the impact of such gear on biodiversity and coastal fishing communities should be promoted.

8.5 Fishing gear selectivity

8.5.1 States should require that fishing gear, methods and practices, to the extent practicable, are sufficiently selective so as to minimize waste, discards, catch of non-target species, both fish and non-fish species, and impacts on associated or dependent species and that the intent of related regulations is not circumvented by technical devices. In this regard, fishers should cooperate in the development of .selective fishing gear and methods. States should ensure that information on new developments and requirements is made available to all fishers.

8.5.2 In order to improve selectivity, States should, when drawing up their laws and regulations, take into account the range of selective fishing gear, methods and strategies available to the industry.

8.5.3 States and relevant institutions should collaborate in developing standard methodologies for research into fishing gear selectivity, fishing methods and strategies.

8.5.4 International cooperation should be encouraged with respect to research programmes for fishing gear selectivity, and fishing methods and strategies, dissemination of the results of such research programmes and the transfer of technology.

8.6 Energy optimization

8.6.1 States should promote the development of appropriate standards and guidelines which would lead to the more efficient use of energy in harvesting and postharvest activities within the fisheries sector.

8.6.2 States should promote the development and transfer of technology in relation to energy optimization within the fisheries sector and, in particular, encourage owners, charterers and managers of fishing vessels to fit energy optimization devices to their vessels.

8.7 Protection of the aquatic environment

8.7.1 States should introduce and enforce laws and regulations based on the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating there to (MARPOL 73/78).

8.7.2 Owners, charterers and managers of fishing vessels should ensure that their vessels are fitted with appropriate equipment as required by MARPOL 73/78 and should consider fitting a shipboard compactor or incinerator to relevant classes of vessels in order to treat garbage and other shipboard wastes generated during the vessel's normal service.

8.7.3 Owners, charterers and managers of fishing vessels should minimize the taking aboard of potential garbage through proper provisioning practices.

8.7.4 The crew of fishing vessels should be conversant with proper shipboard procedures in order to ensure discharges do not exceed the levels set by MARPOL. 73/78. Such procedures should, as a minimum, include the disposal of oily waste and the handling and storage of shipboard garbage.

8.8 Protection of the atmosphere

8.8.1 States should adopt relevant standards and guidelines which would include provisions for the reduction of dangerous substances in exhaust gas emissions.

8.8.2 Owners, charterers and managers of fishing vessels should ensure that their vessels are fitted with equipment to reduce emissions of ozone depleting substances. The responsible crew members of fishing vessels should be conversant with the proper running and maintenance of machinery on board.

8.8.3 Competent authorities should make provision for the phasing out of the use of chlorofluorocarbons (CFCs) and transitional substances such as hydrochlorofluorocarbons (HCFCs) in the refrigeration systems of fishing vessels and should ensure that the shipbuilding industry and those engaged in the fishing industry are informed of and comply with such provisions.

8.8.4 Owners or managers of fishing vessels should take appropriate action to refit existing vessels with alternative refrigerants to CFCs and HCFCs and alternatives to Halons in fire fighting installations. Such alternatives should be used in specifications for all new fishing vessels.

8.8.5 States and owners, charterers and managers of fishing vessels as well as fishers should follow international guidelines for the disposal of CFCs, HCFCs and Halons.

8.9 Harbours and landing places for fishing vessels

8.9.1 States should take into account, inter alia, the following in the design and construction of harbours and landing places:

a) safe havens for fishing vessels and adequate servicing facilities for vessels, vendors and buyers are provided;

b) adequate freshwater supplies and sanitation arrangements should be provided;

c) waste disposal systems should be introduced, including for the disposal of oil, oily water and fishing gear;

d) pollution from fisheries activities and external sources should be minimized; and

e) arrangements should be made to combat the effects of erosion and siltation.

8.9.2 States should establish an institutional framework for the selection or improvement of sites for harbours for fishing vessels which allows for consultation among the authorities responsible for coastal area management.

8.10 Abandonment of structures and other materials

8.10.1 States should ensure that the standards and guidelines for the removal of redundant offshore structures issued by the International Maritime Organization are followed. States should also ensure that the competent fisheries authorities are consulted prior to decisions being made on the abandonment of structures and other materials by the relevant authorities.

8.11 Artificial reef's and fish aggregation devices

8.11.1 States, where appropriate, should develop policies for increasing stock populations and enhancing fishing opportunities through the use of artificial structures, placed with due regard to the safety of navigation, on or above the seabed or at the surface. Research into the use of such structures, including the impacts on living marine resources and the environment, should be promoted.

8.11.2 States should ensure that, when selecting the materials to be used in the creation of artificial reefs as well as when selecting the geographical location of such artificial reefs, the provisions of relevant international conventions concerning the environment and safety of navigation are observed.

8.11.3 States should, within the framework of coastal area management plan, establish management systems for artificial reefs and fish aggregation devices. Such management systems should require approval for the construction and deployment of such reefs and devices and should take into account the interests of fishers, including artisanal and subsistence fishers.

8.11.4 States should ensure that the authorities responsible for maintaining cartographic records and charts for the purpose of navigation, as well as relevant environmental authorities, are informed prior to the placement or removal of artificial reefs or fish aggregation devices.

Appendix C. Specification of studied vessels

1. PD vessel

Fishing gear	: Pelagic Danish Seiner
Fishing crew	: 10 – 15 fishers
Fishing time	: Dawn to dusk
Operational profile	: Active - small pelagic fishing
Principal dimension	: LOA = 12 m, B $_{max}$ = 2.5m D = 0.8 m
Material	: Wood
Construction	: 2008
Acquisition	: 2010
Fuel	: Petrol RON 88
Engine	: Yamaha E40GMHL
Year	: 2010
Transom height (mm)	: 571
Dry weight	: 65-68 kg
Engine type	: 2-stroke, in line 2
Displacement (cc)	: 669
Bore x Stroke (mm)	: 78 x 70 mm
Max. RPM	: 4500 – 5500 (recommended)
Compression ratio	: 6.25
Ignition	: CDI
Max fuel consumption	: 20 lt/hr (504 g/kWh)
Gear ratio	: 24/13 (1.85)
Operation method	: Tiller handle
Lubricating system	: Pre-mix
Trim & Tilt method	: Manual
Starter system	: Manual
Source	: Dunia Marine Indonesia (DMI) (2017)

2. TN vessel

Fishing gear	: Trammel net
Fishing crew	: 2-3 fishers
Fishing time	: Dawn to dusk
Operational profile	: Active - demersal fishing
Principal dimension	: LOA = 9.1 m, B_{max} = 2.4 m D = 1 m
Material	: Wood
Construction	: 2015
Acquisition	: 2015
Fuel	: Diesel 48
Engine	: Dongfeng S1115
Year	: 2015
Type	: 4 stroke, 1 cylinder
System	: Turbulence chamber
Bore x stroke	: 115 X 115
Cylinder volume	: 1.194
Compression ratio	: 17:1
Max Power	: 24 HP / 2200
Average power	: 22 HP / 2200
Max fuel consumption	: 254.2 g/kWh
Lubricating oil tank	: 3.5 L
Cooling system	: Water with hopper
Lubricating system	: Mechanical splashing
Starter system	: Manual
Fuel tank	: 18 L
Water tank	: 21 L
Dimension (mm)	: 440 X 910 X 750
Dry weight	: 200 kg

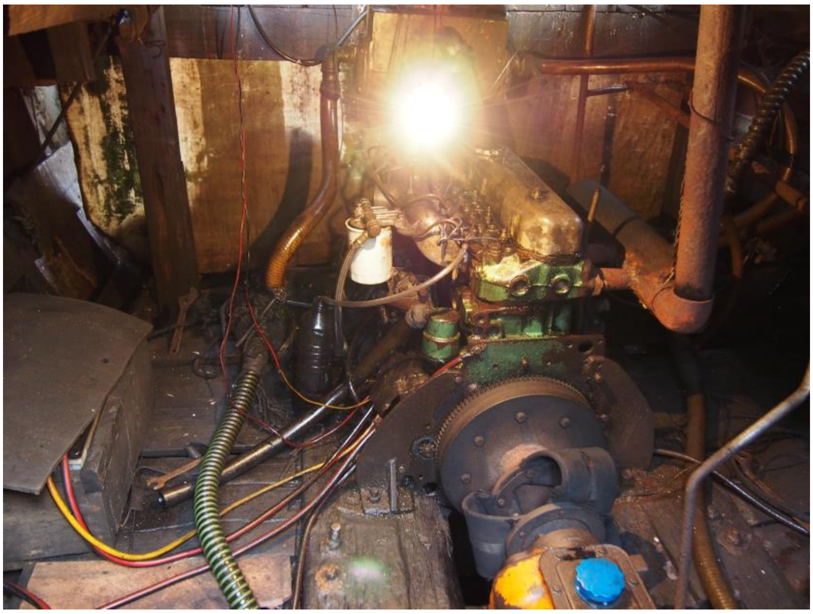
Source : Osmo Marina Mandiri (OMM) (2014)

3. HL vessel

Fishing gear	: Hand line
Fishing crew	: 1-2 fishers
Fishing time	: Dusk to dawn
Operational profile	: Passive - demersal fishing
Principal dimension	: LOA = 9 m, B_{max} = 1.22 m D = 0.75 m
Material	: Wood
Construction	: 2010
Acquisition	: 2010
Fuel	: Diesel 48
Engine	: Yamaha MZ 175
Year	: 2012
Bore × Stroke	: 66 × 50 mm
Displacement	: 171cm^3
Compression Ratio	: 8.5
Max Power (Net)	: 3.5 kW (4.8 PS) / 3600 rpm
Rated Power (Net)	: 3.0 kW (4.1 PS) / 3600 rpm
Max Torque (Net)	: 10.5 N・m (1.0 kgf・m) / 2400 rpm
Max fuel consumption	: 300 g/kWh
Fuel Tank Capacity	: 4.5 L
Ignition System	: T.C.I
Spark Plug	: NGK BPR4ES
Lubrication System	: Mechanical Splashing
Oil Capacity	: 0.6 L
Dry Weight	: 16.0 Kg
Dimensions (L×W×H)	: 315 × 352 × 370 mm
Source	: Yamaha Motor Coorporation (Yamaha) (2017)

4. LF vessel

Fishing gear	: Lift net
Fishing time	: Dusk to dawn
Operational profile	: Passive – small pelagic fishing
Ferry	
Vessel crew	: 1-2 fishers
Principal dimension	: LOA = 13.9 m, B_{max} = 3 m D = 1.32 m
Material	: Wood
Construction	: Not known
Acquisition	: 2000
Fuel	: Diesel 48
Engine	: Mitsubishi 4D31 (Marinised engine)
Year	: 2008
Engine type	: 4 stroke, 4 cylinder
Combustion system	: Direct injection
Max Power	: 100 HP (74.5 KW)/3500 RPM
Cooling system	: Heat exchanger
Starter system	: Electric Starting Motor, DC 24 Volt
Platform	
Platform crew	: 1-2 fisher/platform
Principal dimension	: L = 9 m, B = 9 m, D = 2 m
Material	: Bamboo
Engine	: Generator
Fuel	: Petrol RON 88
Number of platforms	: 10



Appendix D. Respondents involved in the first fieldwork

Stakeholders		Interview method	
		Semi-structured	Structured
Workers	Harvesting		
	1. Fishers/Skippers		
	a. Pelagic Danish seiner		
	Fishers	2	6
	Skippers	2	1
	b. Trammel netter		
	Fishers	2	3
	Skippers	0	1
	c. Hand liner		
	Fishers	2	4
	Skippers	2	3
	d. Lift net ferry	2	0
	e. Lift net platform	2	4
	2. Port-based workers		
	a. Pelagic Danish seiner		2
	b. Trammel netter		2
	c. Hand liner		2
	d. Lift net ferry		2
Value chain actors	1. Vendors		
	a. Boat vendors		5
	b. Other vendors		6
	2. Owners		
	a. Pelagic Danish seiner	2	1
	b. Trammel netter	2	3
	c. Hand liner	2	0
	d. Lift net ferry	2	0
	e. Lift net platform	2	4
	3. Sellers	4	
	4. Fish buyers		6
	5. Second-hand goods buyers		3
Society	1. Influential figures	3	
	2. The government	3	
Local community	3. Fishers' wives		30
	4. Youth		30
Total respondents		**34**	**118**

The roles of the respondents:

1. Fisher is the person who are directly involved in the fish catching process
2. Skipper is the captain of the vessel
3. Port-based worker is the person who are responsible for handling the fishing vessel before and after the fishing operation. This person do not involve in the fish catching process
4. Owner is the person who own the vessel
5. Vendor is the person who sell or produce items required to conduct the fishing operations.
6. Seller is the person who are responsible for selling the fish after the fish being landed in the port.
7. Fish buyer is the person who buy the fish from the sellers.
8. Second-hand goods buyer is the person who buy the used items from the vessel
9. Influential figure is the person who has an impact on how the fishing community act.
10. The government is represented by officers who work in the government institution at the managerial level
11. Fishers' wives include the wife of fishers, skippers and owners
12. Youth is young people in the 13 – 17 age range living near the fishing port

Appendix E. Examples of interview and questionnaire results

Note:
(Type in red): put to make a complete sentence
[Type in blue]: an additional explanation for the previous word
{Type in italic}: describing the situation during the conversation

1. Interview with the seller

Respondent : A.4.3.1

Location : Kiosk at Port

Date : October 07th, 2015

Q : When did you start this business?

A : Since the 80's I have become a seller who takes care of fishermen. I am 50 years old, and I have 4 children and 6 grandchildren. My family does not work like me.

Q : What is the difference between the lift net fishery in the past and in the present?

A : In the present day, the way it works is simple, from lighting using a generator, it does not use kerosene lamp anymore. If there is a problem with the engine/generator, it is enough to bring it to a workshop when it is damaged. Now, the ferry uses inboard engine [diesel engine], while in the past it used the marine outboard engine.

Q : Is there any association for lift net seller?

A : Yes

{Respondent was busy with some notes, to find the bills charged to one of lift net platforms, included cigarettes and petrol. Then he showed the notes to the researcher}

{He was pointing at his notes} This is the fish brought here, this one is processed there. The fishing location is far from Palabuhanratu. This evening, (the fisher) got 18 baskets, but 1 basket was given to the skipper, and 17 baskets remained. This morning, just now, more fish were sent here, but it was not small shrimps. The amount of small shrimps is only 1 basket. So, the total revenue is Rp1,375,000. From the revenue, it is reduced by Rp50,000, for petrol and cigarettes, and the rest is given to the lift net fishers.

(He was pointing at some plastic containers that were full of petrol) These! The fisher does not come here, so we buy petrol here [Palabuhanratu], whilst he stays there [Cibutuh]. So, these are for remote platforms. Coincidentally the fisher is a

Cibutuh resident. If the fishers are Palabuhanratu residents, sometimes they commute by road transportation. [In this case] Because the fisher lives in Cibutuh, some fish is processed there. The fisher just uses a small boat to get to the platforms. He only sends messages via SMS to tell (me) how much fuel needed and the amount of the catch, so the communication runs smoothly. Containers for fuel will just be transferred through the skipper.

Q : Are there any fishers asking you to keep their money?

A : I can save the money for them [to be withdrawn during the full-moon], but it is not always taken during the full moon. By the time he needs it, he could withdraw it. I just need to keep the record of any inflowing and outflowing cash.

Q : Do you like being a seller?

A : Alhamdulillah, it is tiring, but I can help them all. The key is cooperation from the heart to heart and knowing his family. For example, there was a platform crashed by a larger vessel, we were taking care of that issue. (I helped too) establish a communication with the perpetrators and find a solution. If (the perpetrators) respond, then the problem is solved at that very moment, but if (they) do not, I will take legal action.

Q : But, did they respond well?

A : Yes they did because it [the larger vessel was from] was from a big company

Q : Was it the ship from PLTU [steam power plant located near the fishing port]?

A : No, it was a longliner. It is a big company, uses large vessels. The material of the platform was from bamboo, so it is nothing compared to their vessels. When being crashed, it would be destroyed quickly. So we communicated well the other day. Apparently, they accepted it. The crashed vessel was halted by our ferry [at sea]. Otherwise, they would definitely run away. When being stopped [the vessel that was crashed], he [the skipper] said, "Yes, just contact my boss". Then, a fisher got the name, and the (telephone) number of the boss, (he) reported to me, and I contacted the boss. When they were reached, it turned out that they received it [agreed to pay the compensation].

Q : What kind of program is suitable for improving the economy of the lift net fishers? Is it like technical support, for example providing fishing gears which can increase fishermen's income? Or the condition is already good now.

A : to be more successful, there have been some suggestions already, (and) some excellent tools. The government has helped. Like (the development of) lamps that can be sunk. But it is all stuck. It looks like fishers are already comfortable with the current situation. But if there is a technology that is acceptable, why not. They can accept it. (However) before accepting, there should be a trial first. If it is good, then it is acceptable. We will not use any technological advancement if it only makes things more complicated, what a waste.

Q : Is there any conflict?

A : Nothing, we maintain our cooperation with each other. Even if there are clashes, it will be appropriately resolved. There has never been a clash, (or) riot (here). Here, it is so diverse, (there are) people from Batak, Ambon, Sunda, Java, and Bugis [names of some Indonesian tribes]. (But) Palabuhanratu is a safe place. If there is a troublemaker, supposedly, it is inflicted by a different mindset. There is a friction between residents, and that is considered normal. For example, due to a market construction project, loading and unloading facilities [at the fishing port] are used for a temporal market. But the fishers realize (that) they [the traders] have stomach [need money for the living] too, they need to trade. Moreover, we need to consider each other. This loading and unloading areas should be the fishers' areas, we only think, they (the traders) will not be here if the new building for the market is ready. Indeed, some people do not like it, but with a little approach, they will understand.

Q : Does this mean that the benefits of this port are felt by surrounding communities, does not it?

A : Yes, entirely correct. Later on, if there are more development projects such as containers, maybe more people will migrate here. For example, in Tanjung Priok [the major Indonesian port], it is different [now and then]. The thuggery is different. Hopefully, that [the thuggery] will never happen here. Here, the nomadic fishers respect the local people.

Q : What is your response to the prohibition of lift net?

A : if it is prohibited, as long as it (the policy) is clear and there is a compensation [that are acceptable for the fishers]. It is easy just to prohibit it, but the impacts on fishers must be considered. (The government) Must be able to protect the fishers. Speaking is easy, but in reality, it is shoddy.

Q : Do you have other businesses?

A : I supply fresh tuna to a Japanese restaurant in Lippo Cikarang [name of a specific area]. But they pick up the fish here because I have a job here. Unless if the buyer is sick, but he/she needs fish stocks, then I will deliver it.

Tuna from Palabuhanratu has good quality, although it is not red or half red [the colour of the fresh tuna meat], the taste does not change. (It is just) Normal. But if it [the tuna] is from outside (Palabuhanratu), the tuna is filleted and frozen, still red, but it tastes different. So, the red colour might be artificial. From Palabuhanratu, it has natural red colour.

(I) supply tuna once in a week, about 2 quintals per delivery. The delivered fish is not only tuna, but also mackerel, and octopus. (It is at least) 10 types of fish, approximately weighed between 200-250 kg, if there is not enough supply, it is around 50-100 kg. The fish should be hygienic, and then it is ready to be processed for sashimi.

Q : are those tunas from troll line vessels?

A : Yes, but sometimes (I get it) from hand liners, during the peak season. Most of the longliners' catch is frozen and directly sent to the cold storage.

Q : During the peak season, the catch is plentiful. But, during the low season, do fishers get any income?

A : Now, it is peak season, but the waves should be considered. If it is rough [the waves], beware, dirty water would not make fish come. But if it is not [calm waves], and (the water) is not dirty, then all fish will come. (The respondent did not answer the question about the low season)

Q : How much the fishers can earn during the low season?

A : A little, at least the fuel expenses are paid off, just for fuel.

Q : On average, will the price of the catch reach Rp100,000 per basket?

A : Yes, small shrimps could reach Rp120,000.

During the peak season, (the income) might reach 10 million rupiahs in just a few days or one week. If it is really at the highest point, it might reach 40 million rupiahs. For example, for one kilo of bullet tuna consisting of 6 or 7 fish, might be sold up to 2 tonnes a day, (or) at least 5 quintals. When it happens, I cannot even sleep. At the busiest season, at 7:30 p.m. (I) am going to be called from the sea [platforms]. If they [the fishers] need more baskets. (I will just ask them to) hang (the fish) in the net. Supposedly, (I will ask them) about the number of baskets left, and if they say none. So, I will send more empty baskets immediately. It happens only if the catch is truly abundant. It might reach to 100 baskets weighed 20-25 kilo/baskets.

Q : Where do you sell the fish?

A : Oh, just like Tuna, there is already a customer, who buys from me. Usually, it is brought to Jakarta.

Q : How is the business competition here?

A : It is normal; it is called business. But I believe that destiny will not be swapped. The important thing is how to organise the cooperation with fishers.

Q : If there is a new seller, is it difficult to enter this business?

A : It is okay. In my case, if a fisher wants to move to another seller, it is fine, as long as the business with me is done. If there is a new seller, the key is (he should have) enough fish supply and customers.

Q : Is there any training/supervising programmes from the government?

A : No, but there is an appeal for not catching any prohibited fish

Note:
(Type in red): put to make a complete sentence
[Type in blue]: an additional explanation for the previous word
{Type in italic}: describing the situation during the conversation

2. Interview with the influential figure

Respondent : I.4.0.1

Location : Respondent's house

Date : October 10th 2015

Q : How long have you been a fisher?

A : I have been fishing since I was young

Q : Were you from Palabuhanratu?

A : I am a Buginese (one of the tribes in Indonesia), I am from Sulawesi. I came here in 1966 with my family. However, all of them have already died, and it is only me left now.

Q : When you came to Palabuhanratu, did you immediately work on the lift net fishing or on other fishing?

A : I started working on the lift net fishing, however, I worked using a static lift net platform. Then I switched to a boat lift net, and now I work at a lift net ferry (to serve the floating platforms). A floating lift net platform is made of plastic containers, as floats, with bamboo (construction) on top of it, while the lift net ferry is a wooden vessel.

Q : Is a boat lift net [a type of lift net which is directly attached to a boat, not separately floated] dominating in Sulawesi [the land where Bugis tribe came from]?

A : Yes. However, the one we use here is not as big as what we used in Sulawesi, a boat lift net in Sulawesi was bigger in dimension compared to the one in Palabuhanratu. In Palabuhanratu, the boat itself is 15 m length.

Q : How old is your ferry?

A : It is more than 20 years old. But it experienced a major repair by the damaged materials being replaced with a new one.

Q : When did you buy the vessel?

A : The vessel was made here [in Palabuhanratu], and operated by its previous owner before I bought it. If I am not mistaken, I recall that the vessel was made in 80'. I bought it in the early 90's and fixed it.

Q : When was the last maintenance?

A : The maintenance will be performed if there is a damaged component. The wooden material was replaced with a new one approximately around 6 months ago.

Q : About the maintenance itself, is there any particular time to do it?

A : There is no particular time, it all depends on the level of damage. When many parts should be fixed, the maintenance cost will be high. I spent around 100 million (in rupiah) to fix the vessel 5 years ago. Almost all parts were replaced.

Q : Did you change the engine?

A : Yes, I did, it was Yanmar 33 PK, and however I changed it with a truck engine.

Q : The truck engine is not for on-board use, right? Who modified the engine?

A : There is a mechanic who takes care of the ferry. He said that the truck engine would be easier to use since you [the skipper] do not have to crank the engine to start it, you [the skipper] only need to push the starter button. I followed his recommendation, and indeed it was more comfortable. However, the fuel consumption becomes higher afterwards.

Q : Do you have experiences in running another fishery other than lift net?

A : Yes, I do, I operated gillnet using my vessel [before, it was functioned as a ferry].

Q : But you are not using gillnet now? Why?

A : The result is not as much as it was. Many fishers stopped operating gillnet

Q : How does the ferry's owner find the vessel's crew and fishers who want to join the ferry?

A : Usually the fishers come to the owner of the ferry and ask for permission, if there are no troubles found with other people, usually they will be accepted to join. However, if they come from other ferries, it should be checked if there are any personal issues or not. They should solve their problems first before joining another ferry.

Q : Is there any misunderstanding happened between the fishers?

A : Yes there is, they often get jealous of other fishers. When they do not catch any fish from their lift nets [at the spot where the lift net is floated], they will ask (the skipper) to move (the lift net) to another spot with better fish production. However, they sometimes are impatient and get angry easily because the skipper does not move (the lift net) as soon as possible. Hence, they move to another ferry.

Q : Can you tell me the development of lift net fishery in Palabuhanratu?

A : Actually I am one of the first people who introduced the lift net in Palabuhanratu. Back then, all lift nets were owned by the fishers from Sulawesi. I started to have a boat in 1973 with Yamaha outboard engine. The ferry was built like the pelagic Danish seiner. I changed the engine with Yanmar since it started to use diesel fuel. Diesel fuel was cheaper than any other kinds of fuel. The newest model is the truck engine that I have been using until now.

At that time, there only a few ferries existed. Not many people had it. Then when other people started to have ferries, some of the fishers on my ferry moved (to join other ferries). So now my ferry only serves 10 lift net platforms.

Q : Are there any significant changes in the lift net fishery from old to present era?

A : Yes, now the fishing equipment is better, and it makes everything easier than before. For example, the light used on the lift net. Fishers in old era used kerosene lamp while fishers in the present era use a generator. Now, fishers can sleep without worrying about the lamp to be off. Besides, they do not have to pump the lamp to keep the light on.

Q : How about the fishing grounds, is there any change?

A : Not really, the fishing grounds are just along the coast depending on the targeted fish. Currently, the fishing ground is near to the coast, however, (in a different season) the fishing grounds can be far away. We can operate the lift net up to Jampang [name of a specific area along the bay].

Q : Does it mean that your ferry will tow the lift net platforms there [Jampang]?

A : Yes, usually one or two lift nets will be moved to a new fishing ground, if the catch is good then all of the lift nets will be moved to the designated fishing ground.

Q : How about the number of lift net fishers, is it increasing?

A : Yes. Many people are interested in the lift net fishery.

Q : When was the last time you operate the lift net?

A : The last time I went to the sea and operated lift net was in 1976. Then I retired and made salted fish with anchovies, mackerel and small shrimp. Now, at this age, I only do what I like to do.

Q : How do you think about the accident at sea? Does it happen frequently?

A : There was an incident that happened in the last Ramadhan [an Islamic fasting month], a fisher died on the lift net. No one knew the cause, his friends said that he was all right before, but other fishers found him already dead when the ferry came to pick him up. There was also an incident where a fisher was struck by lightning.

Q : Is there any safety equipment provided at the lift net?

A : No, since we can call for help in case of emergency. Back then, we could not call for help since there were no cell phones. We had to wait for the ferry to pick us. Shouting was sometimes useless since it would not be heard by anyone due to the long distance between lift nets.

Q : How about the culture, I saw the pelagic Danish seiner fishers showering the gear [using special/sacred water] before departing to the fishing ground, is it common here?

A : I am not sure about that, but some of them believe in that, and it works for them. To me, I have never done that kind of ritual. I prefer to pray to God.

Q : Regarding the lift net, is there anything changing?

A : The shape is still the same. However, it was used to be operated as a boat lift net, and the mast was higher than it is nowadays.

Q : What will be the future of lift net fishers like?

A : I do not know, it all depends on the government. If they decide to forbid the lift net, I think that will significantly impact the fishers. They only know how to work as lift net fishers, if it is banned all of a sudden, what can they do for a living?

Q : If it is banned, what is the best compensation for them?

A : I think, as a fisher, it would be hard to forbid them. It is not easy to find another job that suits them.

Q : Have you ever do any inland-based job?

A : Yes, I have, but only as a side job. Still, my main job is a fisher. Not all fishers can switch their job into inland-based one. Also, most of them do not have land property to be cultivated. If they opt to work [farming or logging] in the mountain, the income is not as good as a fisher.

Q : How many children do you have? Do any of them work in the fisheries sector?

A : I have 3 children. Only one work in the fisheries-related sector, but (my child) works at an office [fishing port]

Q : Are parents here teach their children to be a better fisher, or support their children to be a fisher?

A : I personally do not want my child to be a fisher. Being a fisher is hard, that is why I told them to study hard, so they can find a better job.

Q : Is your income also taken monthly just like others?

A : Yes. My income is taken every month. Sometimes I get some profit, sometimes (I) I experience some loss. During the full moon, after (the net income is) deducted by fuel cost, if there is a profit, it will be shared with the fishers.

Q : Well, does it mean that the seller is the only person who records the sales? Do you have your own note?

A : I have. I record it myself. I write a profit or loss every day.

Q : How about the young generation in this area, are they interested in working as a fisher?

A : Nowadays, not many Bugis people want to be a fisher. Most of the young fishers are from Palabuhanratu. Bugis people prefer to work at the office.

Q : Are there any differences between the social level of the ferry owner and crew?

A : No. It is just about different responsibility. The owner has to provide the operational cost [for the ferry].

Q : How about the cost, how much do you provide every day?

A : That depends on the location of the lift net. If the location is near, it only costs Rp250,000/day, however, if the location is far, let say to Jampang, then I have to provide up to Rp700,000/day.

Q : What do you think about by-catch, is it better to sell it?

A : It will be sold since it has commercial value

Q : Do you think the fishers also keep maintaining the environment?

A : Yes, they were used to be fishers using bombs, but other fishers complained since it is dangerous. Also, there was a mini trawl operating in Palabuhanratu, but other fishers did a protest to stop it.

Q : According to my observation, the fishers caught lots of fish lately, is it a peak season now?

A : You are right, the amount of fish is starting to increase, but it is not peak yet.

Q : Then, when will the peak season happen?

A : In this month we can catch small shrimps and *selayar* fish [local name], however, *jabon* fish [local name] was also caught a few weeks ago.

Q : During the low season, what do the fishers do if they are not fishing?

A : Mostly they will stay at home, (and) find another job. (They might) Become a construction worker or else.

Q : Is the ferry operated during the low season?

A : Nope, usually it is not operated during December – January due to bad weather.

Q : Do Sulawesi people operate other fishing gear, such as pelagic Danish seiner?

A : Nope, no Bugis people has a pelagic Danish seiner in Palabuhanratu.

Q : How about PLTU [a steam power plant built near the fishing port], does it have an impact on lift net fishery?

A : No. Some people spread the issue that PLTU would drive the fish away. They also spread the same problem when the government planned to build vessel dockyard at the fishing port. The point is you can get fish if there is fish in that area and vice versa. The PLTU can be beneficial for the residents.

Q : Is there any grant or donation programme from the PLTU?

A : Yes. Last year, they gave us 1 roll of rope for each lift net fisher.

Q : It is dry season now, is the fish still abundant?

A : Well, it depends on the time. In a dry season like this, the operation will take longer than usual.

Q : Do you receive your income from the seller?

A : Yes, sometimes I get some income if the catch is good and sometimes I lose if the catch is bad.

Q : Can you tell me about the sharing system?

A : On 17th every month [in Islamic/Lunar calendar], the income will be shared. 20 % of the revenue will be given to the skipper. If the profit is 1 million, Rp200,000 will be given to the skipper. The remaining is for engine maintenance and for me.

Q : Is the ferry maintenance performed by the skipper?

A : For an oil change, yes, as for the hull maintenance and repainting will be taken care of by a particular worker.

Q : Can you tell me how Palabuhanratu looked in the past time?

A : There were no houses like nowadays. The house only had a few rooms. You needed to take public transportation from Bogor to Cibadak and then continued from Cibadak to Palabuhanratu [explaining the access from the nearest big city]. This road did not even exist at that time, not even the fishing port. It was so quiet. When I was moving here for the first time, pelagic Danish seine was operated using a small boat without an engine. The fishing ground also was not far from the coast, until Cikeuer [name of the specific location near the fishing port] and many people just fished on the shore.

Q : Which one do you prefer, working in a large vessel with a longer trip or in a small vessel with a shorter trip?

A : As an owner, I prefer a large vessel to a small one. However, the large (vessel) will need more money, and I do not have that much money.

Q : So, do you think fishers here do not like to go on a long trip of fishing?

A : Not many people here want to go on a long fishing trip, on the contrary, Javanese [another Indonesian tribe] fishers usually go on a long fishing trip which takes months to get back to the port.

Q : Do you also build a vessel?

A : Nope

Q : Are there any differences between vessels built by Sulawesi and Palabuhanratu people?

A : Yes, different tribes have their own methods when building vessels. In Sulawesi, the people who build a vessel are called Bugis Bajo. Meanwhile, in Palabuhanratu, vessels are built by Javanese. The level of durability depends on the users. We have to perform regular maintenance and repair the vessels if there is any damage.

Q : Should the vessel that will be operated in Palabuhanratu waters, be made here?

A : Not really, there are vessels made in Sulawesi and then brought here.

Q : Are the fishers (who use the vessel) also from Sulawesi?

A : Some of them are from Sulawesi, some others are not.

Q : Are the vessels in Palabuhanratu being laminated by fibreglass?

A : For small vessels yes, but not for larger ones since the cost will be even higher. However, if the vessels belong to a company with a lot of money, the vessels might be laminated using fibreglass.

Q : When did the conversion to fibreglass vessel start?

A : I do not know exactly, it happened recently. Especially for small pelagic Danish seiners and hand liners, it happened approximately 5 years ago.

Q : Is it possible to convert the existing ferries into fibreglass vessels?

A : I do not know, it seems complicated.

Q : Is it possible to do laminating on the existing ferry?

A : It is possible, but it will be costly because you need to change the old planks before the lamination.

Q : Which one is more expensive, a wooden or a fibreglass vessel at the same dimensions?

A : I think fibreglass

Q : What kind of wood is usually used to build a vessel?

A : For the keel and underwater areas, we use Damar Laut [type of hardwood], (whilst) for the upper hull we use Bayur [different types of wood]. The keel has never been replaced since the vessel was made.

Q : By the way, how about the fish? Do you think it is different compared to the old days?

A : There is a saying that *"if there are no more leaves on land, there will be no more fish"*. This means that there will be fish as long as there are leaves on land. Fish would not be running out. It is just about the seasons.

Q : What is your concern about the technical development in fisheries?

A : Most importantly, it has to benefit the fishers, and they need to be informed in advance. Fishers here are open to new technology. However, they need to prove it themselves first.

Q : Is there any issue related to corruption?

A : Yes, mainly related to the government. However, there is no evidence to prove it.

3. Questionnaire results from fishers

No	Questions	Answer		
		Yes	No	Idk
	Family Background			
1	You are from fishers family	20	10	-
2	You become a fisher voluntarily	24	6	-
3	You have a younger family member who also a fisher	15	15	-
4	They become a fisher voluntarily	15	15	-
5	You support or teach a younger family member to become a fisher	4	26	-
6	You do not want a younger family member to become a fisher	30	-	-
	Occupation			
7	Fisher is your first job	21	9	-
8	Fisher is your main job	27	3	-
9	You plan to resign as a fisher soon	13	17	-
10	If you resign, you plan to find another job	18	6	6
11	You have experiences working in the larger vessel with a longer trip	-	30	-
12	You expect to work in a larger vessel with a longer trip	-	30	-
13	Becoming a fisher need special skills	27	3	-
14	Becoming a fisher need formal education	3	27	-
15	You prefer working as a fisher than any other land-based jobs	10	20	-
16	You have an experience working with more than one fishing gear	10	20	-
17	You plan to work with different gear in the near future	4	26	-
18	Discrimination occurs on board	-	30	-
19	Discrimination occurs within the local community	-	30	-
20	The sharing system is fair	30	-	-
21	You are free to make any decision regarding your job	29	1	-
22	You prepare health and safety tools before going fishing	1	29	-
23	You can swim	30	-	-

No	Questions	Answer		
		Yes	No	Idk
24	You had experienced an occupational accident at sea	11	19	-
25	You have seen an occupational accident at sea	29	1	-
26	You have used health service provided in the fishing port	29	1	-
	Environmental issue			
27	The fishing operation may result in air/water pollution	14	-	16
28	Pollution is derived from the engine and onboard activities	30	-	-
29	Pollution from the vessel may disturb the marine ecosystem	19	-	11
30	Pollution from the vessel may affect human health	30	-	-
31	You sold all type of the catch	29	1	-
32	You sold all size of the catch	23	7	-
33	The size of fish is decreasing	24	6	-
34	The decreasing of fish size is the indicator of damaged marine environment	1	1	28
35	The fish production is decreasing	30	-	-
36	The decreasing of fish production is the indicator of damaged marine environment	2	-	28
37	There is a gear which might damage the marine environment	2	28	-
38	Fish resources in Palabuhanratu are nearly overfished	-	28	2
	Economic issue			
39	You have savings	26	4	-
40	You have assets such as a house, cars, motorcycle	30	-	-
41	You bought that asset	23	7	-
42	Your wife is working	4	26	-
43	You have additional income	5	25	-
44	You have a financial record for your fishing activities	-	30	-
45	You can pay off most of your debt during peak season	26	4	-
46	Fishing with a larger vessel, further fishing ground and longer trip will increase your income	9	19	2
	Social issue			

No	Questions	Answer		
		Yes	No	Idk
47	There is a conflict between a group of fishers from different fishing gears	-	30	-
48	There is a conflict between a group of fishers from different race/ethnicity	-	30	-
49	Nowadays, more young generation become a fisher	14	16	-
50	Young generation become a fisher due to no other choices	30	-	-
51	Young generation become a fisher voluntarily	30	-	-
52	Before involving in fishing activities, the young generation need training from the experienced fishers	28	2	-
53	You had received a grant from government/company	20	10	-
54	You had received training from government/company	18	12	-
55	The fishers working group and fishers association are working well as expected	1	-	29
56	You are happy to be involved in technical advancement programme	28	-	2
57	Fisheries is very important for the economic development in Palabuhanratu	30	-	-
58	The number of senior fishers is higher than the junior ones	30	-	-

Appendix F. Example of one-month observation record

Vessel A : PD vessel
Owner : O.1.0.1
Skipper : F.1.2.1
Seller : A.1.3.1
Period of observation : October 2015

Date	Day fishing	Input			Fishers (person)	Output	
		Fuel (litre)	Lubricant (litre)	Ice (block)		Catch (Kg)	Price (IDR)
1 Oct 2015	Fishing	60.00	2.00	3.00	12	935.00	9,000,000.00
2 Oct 2015	Off						
3 Oct 2015	Fishing	90.00	3.00	3.00	15	610.00	5,500,000.00
4 Oct 2015	Fishing	90.00	3.00	3.00	15	490.00	4,400,000.00
5 Oct 2015	Fishing	60.00	2.00	3.00	14	315.00	2,800,000.00
6 Oct 2015	Off						
7 Oct 2015	Fishing	60.00	2.00	3.00	13	280.00	3,950,000.00
8 Oct 2015	Fishing	60.00	2.00	4.00	10	80.00	880,000.00
9 Oct 2015	Off						
10 Oct 2015	Fishing	90.00	3.00	4.00	14	278.00	2,780,000.00
11 Oct 2015	Fishing	90.00	3.00	2.00	15	585.00	5,850,000.00
12 Oct 2015	Fishing	90.00	3.00	2.00	13	1,020.00	13,300,000.00
13 Oct 2015	Fishing	90.00	3.00	4.00	15	0.00	0.00
14 Oct 2015	Fishing	120.00	4.00	3.00	15	220.00	3,080,000.00
15 Oct 2015	Fishing	120.00	4.00	3.00	15	290.00	2,800,000.00

Date	Day fishing	Input			Fishers (person)	Output	
		Fuel (litre)	Lubricant (litre)	Ice (block)		Catch (Kg)	Price (IDR)
16 Oct 2015	Off						
17 Oct 2015	Fishing	90.00	3.00	4.00	14	275.00	2,800,000.00
18 Oct 2015	Fishing	90.00	3.00	3.00	15	665.00	9,310,000.00
19 Oct 2015	Fishing	90.00	3.00	4.00	15	965.00	9,500,000.00
20 Oct 2015	Fishing	90.00	3.00	2.00	17	0.00	0.00
21 Oct 2015	Fishing	90.00	3.00	2.00	14	185.00	1,750,000.00
22 Oct 2015	Off						
23 Oct 2015	Fishing	90.00	3.00	4.00	13	0.00	0.00
24 Oct 2015	Fishing	90.00	3.00	3.00	15	150.00	1,500,000.00
25 Oct 2015	Fishing	90.00	3.00	2.00	15	260.00	3,000,000.00
26 Oct 2015	Fishing	90.00	3.00	2.00	14	512.00	6,100,000.00
27 Oct 2015	Fishing	120.00	4.00	3.00	12	645.00	7,500,000.00
28 Oct 2015	Fishing	120.00	4.00	2.00	10	100.00	800,000.00
29 Oct 2015	Fishing	120.00	4.00	2.00	10	50.00	450,000.00
30 Oct 2015	Off						
31 Oct 2015	Fishing	120.00	4.00	2.00	14	321.00	3,200,000.00
Total		**2,310.00**	**77.00**	**72.00**		**9,231.00**	**100,250,000.00**
Average		**92.40**	**3.08**	**2.88**		**369.24**	**4,010,000.00**

Appendix G. Fishing operation model–profit model

The model consists of three parts; A) Data input, B) Profit calculation for common, optimistic and pessimistic scenarios, C) Result

1. PD vessel

A. Data input

1. Fishing pattern

Month	Trip	Fuel	Catch/trip	Fish Price
January	Moderate	Moderate	Low	Moderate
February	Moderate	Low	Low	Moderate
March	Moderate	Low	Low	Low
April	Low	Moderate	Low	Moderate
May	Low	Moderate	Moderate	Moderate
June	Low	Peak	Low	Peak
July	Moderate	Peak	Peak	Peak
August	Moderate	Peak	Peak	Moderate
September	Peak	Peak	Peak	Low
October	Peak	Peak	Peak	Low
November	Moderate	Peak	Moderate	Moderate
December	Low	Moderate	Moderate	Peak

2. Input variables

Variable	Peak	Moderate	Low
Fishing days (day/month)	25	20	12
Successful trip (%)	90%	80%	70%
Optimistic	100%	90%	80%
Pessimistic	80%	70%	60%
Fuel/trip (litre)	120	90	60
Fuel price (Rp)	6,550	6,550	6,550
Lubricant/trip (litre)	4	3	2
Lubricant price (Rp)	30,000	30,000	30,000
Ice/trip (kg)	63	63	63
Ice price (Rp)	500	500	500
Catch/trip (kg)	500	300	150
Fish price (Rp/kg)	13,000	10,000	6,500
Number of fishers	10		
Number of worker	3		
Currency converter (Rp)	16,555		

3. Sharing system

Shareholder	Percentage
Seller	10%
Owner*	67%
Fishers*	33%
Worker	5%

*The percentage from 100% net revenue (after deducted by 10% for the seller)

B. Profit calculation

1. Common

Month	General		Fuel			Lubricant			Supplies			Catch			Total cost (Rp)	Total Revenue (Rp)	Seller share (Rp)	Profit/month (Rp)			
	Trip (day)	Successful trip (%)	Fuel/trip (litre)	Fuel/month (litre)	Fuel price (Rp)	Lubricant/ trip (litre)	Lubricant/ month (litre)	Lubricant price (Rp)	Ice/trip (kg)	Ice/month (kg)	Ice price (Rp)	Catch/trip (kg)	Catch/month (kg)	Fish price (Rp)				Fishing vessel	Owner	Fisher	Worker
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
January	20	80%	90	1,800	6,550	3	60	30,000	63	1,260	500	150	2,400	10,000	14,220,000	24,000,000	2,400,000	21,600,000	-1,980,000	720,000	720,000
February	20	80%	60	1,200	6,550	2	40	30,000	63	1,260	500	150	2,400	10,000	9,690,000	24,000,000	2,400,000	21,600,000	2,550,000	720,000	720,000
March	20	80%	60	1,200	6,550	2	40	30,000	63	1,260	500	150	2,400	6,500	9,690,000	15,600,000	1,560,000	14,040,000	-1,734,000	468,000	468,000
April	12	70%	90	1,080	6,550	3	36	30,000	63	756	500	150	1,260	10,000	8,532,000	12,600,000	1,260,000	11,340,000	-2,106,000	378,000	378,000
May	12	70%	90	1,080	6,550	3	36	30,000	63	756	500	300	2,520	10,000	8,532,000	25,200,000	2,520,000	22,680,000	4,320,000	756,000	756,000
June	12	70%	120	1,440	6,550	4	48	30,000	63	756	500	150	1,260	13,000	11,250,000	16,380,000	1,638,000	14,742,000	-2,896,200	491,400	491,400
July	20	80%	120	2,400	6,550	4	80	30,000	63	1,260	500	500	8,000	13,000	18,750,000	104,000,000	10,400,000	93,600,000	34,290,000	3,120,000	3,120,000
August	20	80%	120	2,400	6,550	4	80	30,000	63	1,260	500	500	8,000	10,000	18,750,000	80,000,000	8,000,000	72,000,000	22,050,000	2,400,000	2,400,000
September	25	90%	120	3,000	6,550	4	100	30,000	63	1,575	500	500	11,250	6,500	23,437,500	73,125,000	7,312,500	65,812,500	13,856,250	2,193,750	2,193,750
October	25	90%	120	3,000	6,550	4	100	30,000	63	1,575	500	500	11,250	6,500	23,437,500	73,125,000	7,312,500	65,812,500	13,856,250	2,193,750	2,193,750
November	20	80%	120	2,400	6,550	4	80	30,000	63	1,260	500	300	4,800	10,000	18,750,000	48,000,000	4,800,000	43,200,000	5,730,000	1,440,000	1,440,000
December	12	70%	90	1,080	6,550	3	36	30,000	63	756	500	300	2,520	13,000	8,532,000	32,760,000	3,276,000	29,484,000	8,175,600	982,800	982,800
Total	218			22,080			736			13,734			58,060	9,875	173,571,000	528,790,000	52,879,000	475,911,000	96,111,900	15,863,700	15,863,700

Note: the same procedure is applied for optimistic and pessimistic scenarios.

C. Result

1. Monthly profit received by shareholders (£)

Month	Common				Range Max				Range Min			
	Owner	Fisher/Skipper	Worker	Seller	Owner	Fisher/Skipper	Worker	Seller	Owner	Fisher/Skipper	Worker	Seller
January	-120	43	43	145	92	5	5	18	92	5	5	18
February	154	43	43	145	92	5	5	18	92	5	5	18
March	-105	28	28	94	60	4	4	12	60	4	4	12
April	-127	23	23	76	55	3	3	11	55	3	3	11
May	261	46	46	152	111	7	7	22	111	7	7	22
June	-175	30	30	99	72	4	4	14	72	4	4	14
July	2,071	188	188	628	400	24	24	79	400	24	24	79
August	1,332	145	145	483	308	18	18	60	308	18	18	60
September	837	133	133	442	250	15	15	49	250	15	15	49
October	837	133	133	442	250	15	15	49	250	15	15	49
November	346	87	87	290	185	11	11	36	185	11	11	36
December	494	59	59	198	144	8	8	28	144	8	8	28
Total	**5,806**	**958**	**958**	**3,194**	**2,022**	**119**	**119**	**396**	**2,022**	**119**	**119**	**396**

2. Profit analysis (£)

Component	Value	Percentage	Range	
			Max	Min
Total revenue	31,941	100%	3,964	3,964
Supplies cost	-10,485	33%	0	0
Selling cost	-3,194	10%	396	396
Personnel cost	-12,457	39%	1,546	1,546
Owner's Profit	5,806	18%	2,022	2,022
Fisher	958	3%		

3 Profit and expenditure (£)

Shareholder	Profit	Annual CAPEX	Annual OPEX-maintenance	Range	
				Max	Min
Owner	5,806	-503	-1,365	2,022	2,022
Fisher/Skipper	958	0	0	119	119
Worker	958	0	0	119	119
Seller	3,194	0	0	396	396

Note: Maximum and minimum ranges are obtained from optimistic and pessimistic scenarios

2. TN vessel

A. Data input

1. Fishing pattern

Month	Trip	Fuel	Catch/trip	Fish Price
January	Moderate	Moderate	Peak	Moderate
February	Peak	Low	Moderate	Peak
March	Peak	Low	Peak	Low
April	Low	Low	Peak	Low
May	Low	Low	Peak	Low
June	Low	Low	Moderate	Low
July	Moderate	Low	Low	Low
August	Moderate	Low	Moderate	Peak
September	Moderate	Low	Moderate	Low
October	Peak	Low	Low	Low
November	Peak	Peak	Peak	Low
December	Peak	Low	Low	Moderate

2. Input variables

Variable	Peak	Moderate	Low
Fishing days (day/month)	25	20	12
Successful trip (%)	90%	80%	70%
Optimistic	100%	90%	80%
Pessimistic	80%	70%	60%
Fuel/trip (litre)	30	25	15
Fuel price (Rp)	5,150	5,150	5,150
Ice/trip (kg)	25	25	25
Ice price (Rp)	500	500	500
Catch/trip (kg)	25	15	5
Fish price (Rp/kg)	55,000	45,000	25,000
Number of fishers	3		
Currency converter (Rp)	16,555		

3. Sharing system

Shareholder	Percentage
Owner	50%
Fishers	50%

B. Profit calculation

1. Common

Month	General		Fuel			Supplies			Catch			Total cost (Rp)	Total Revenue (Rp)	Profit/month (Rp)	
	Trip	Successful trip (%)	Fuel/trip (litre)	Fuel/month (litre)	Fuel price	Ice/trip (kg)	Ice/month (kg)	Ice price (Rp)	Catch/trip (kg)	Catch/month (kg)	Fish price (Rp)			Owner	Fisher
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
January	20	80%	25	500	5,150	25	500	500	25	400	45,000	2,825,000	18,000,000	7,587,500	2,529,167
February	25	90%	15	375	5,150	25	625	500	15	338	55,000	2,243,750	18,562,500	8,159,375	2,719,792
March	25	90%	15	375	5,150	25	625	500	25	563	25,000	2,243,750	14,062,500	5,909,375	1,969,792
April	12	70%	15	180	5,150	25	300	500	25	210	25,000	1,077,000	5,250,000	2,086,500	695,500
May	12	70%	15	180	5,150	25	300	500	25	210	25,000	1,077,000	5,250,000	2,086,500	695,500
June	12	70%	15	180	5,150	25	300	500	15	126	25,000	1,077,000	3,150,000	1,036,500	345,500
July	20	80%	15	300	5,150	25	500	500	5	80	25,000	1,795,000	2,000,000	102,500	34,167
August	20	80%	15	300	5,150	25	500	500	15	240	55,000	1,795,000	13,200,000	5,702,500	1,900,833
September	20	80%	15	300	5,150	25	500	500	15	240	25,000	1,795,000	6,000,000	2,102,500	700,833
October	25	90%	15	375	5,150	25	625	500	5	113	25,000	2,243,750	2,812,500	284,375	94,792
November	25	90%	30	750	5,150	25	625	500	25	563	25,000	4,175,000	14,062,500	4,943,750	1,647,917
December	25	90%	15	375	5,150	25	625	500	5	113	45,000	2,243,750	5,062,500	1,409,375	469,792
Total	241			4,190			6,025			3,194		24,591,000	107,412,500	41,410,750	13,803,583

Note: the same procedure is applied for optimistic and pessimistic scenarios.

C. Result

1. Monthly profit received by shareholders (£)

Month	Common		Range Max		Range Min	
	Owner	Fisher/skipper	Owner	Fisher/skipper	Owner	Fisher
January	458	153	68	23	68	23
February	493	164	62	21	62	21
March	357	119	47	16	47	16
April	126	42	23	8	23	8
May	126	42	23	8	23	8
June	63	21	14	5	14	5
July	6	2	8	3	8	3
August	344	115	50	17	50	17
September	127	42	23	8	23	8
October	17	6	9	3	9	3
November	299	100	47	16	47	16
December	85	28	17	6	17	6
Total	**2,501**	**834**	**390**	**130**	**390**	**130**

2. Profit analysis (£)

Component	Value	Percentage	Range	
			Max	Min
Total revenue	6,488	100%	780	780
Supplies cost	-1,485	23%	0	0
Personnel cost	-2,501	39%	390	390
Owner's Profit	2,501	39%	390	390
Fisher	834	13%		

3 Profit and expenditure (£)

Shareholder	Profit	Annual CAPEX	Annual OPEX-maintenance	Range	
				Max	Min
Owner	2,501	-344	-1,121	390	390
Fisher/skipper	834	0	0	130	130

Note: Maximum and minimum ranges are obtained from optimistic and pessimistic scenarios

3. HL Vessel

A. Data input

1. Fishing pattern

Month	Trip	Fuel	Catch/trip	Fish Price
January	Moderate	Moderate	Moderate	Peak
February	Peak	Peak	Moderate	Peak
March	Peak	Peak	Peak	Peak
April	Peak	Peak	Moderate	Peak
May	Moderate	Peak	Moderate	Moderate
June	Low	Moderate	Low	Low
July	Low	Moderate	Moderate	Low
August	Low	Low	Low	Low
September	Moderate	Moderate	Low	Moderate
October	Peak	Low	Peak	Low
November	Moderate	Low	Peak	Low
December	Moderate	Low	Peak	Peak

2. Input variables

Variable	Peak	Moderate	Low
Fishing days (day/month)	25	20	12
Successful trip (%)	90%	80%	70%
Optimistic	100%	90%	80%
Pessimistic	80%	70%	60%
Fuel/trip (litre)	12	9	7
Fuel price (Rp)	6,550	6,550	6,550
Lubricant/trip (litre)	0.10	0.10	0.10
Lubricant price	30,000	30,000	30,000
Ice/trip (kg)	25	25	25
Ice price (Rp)	500	500	500
Bait/trip (kg)	3	3	3
Bait price (Rp)	5,000	5,000	5,000
Catch/trip (kg)	30	20	5
Fish price (Rp/kg)	26,000	25,000	24,000
Number of fishers		2	
Currency converter (Rp)		16,555	

3. Sharing system

Shareholder	Percentage
Fee	10%
Owner*	33%
Fishers*	33%
Worker	5%

*The percentage from 100% net revenue (after deducted by 15% for the seller and the worker)

B. Profit calculation

1. Common

Month	General		Fuel			Lubricant			Supplies					
	Trip	Successful trip (%)	Fuel/trip (litre)	Fuel/month (litre)	Fuel price (Rp)	Lubricant/ trip (litre)	Lubricant/ month (litre)	Lubricant price (Rp)	Ice/trip (kg)	Ice/month (kg)	Ice price (Rp)	Bait/trip (kg)	Bait/month (kg)	Bait price (Rp)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
January	20	80%	9	180	6,550	0	2	30,000	25	500	500	3	60	5,000
February	25	90%	12	300	6,550	0	3	30,000	25	625	500	3	75	5,000
March	25	90%	12	300	6,550	0	3	30,000	25	625	500	3	75	5,000
April	25	90%	12	300	6,550	0	3	30,000	25	625	500	3	75	5,000
May	20	80%	12	240	6,550	0	2	30,000	25	500	500	3	60	5,000
June	12	70%	9	108	6,550	0	1	30,000	25	300	500	3	36	5,000
July	12	70%	9	108	6,550	0	1	30,000	25	300	500	3	36	5,000
August	12	70%	7	84	6,550	0	1	30,000	25	300	500	3	36	5,000
September	20	80%	9	180	6,550	0	2	30,000	25	500	500	3	60	5,000
October	25	90%	7	175	6,550	0	3	30,000	25	625	500	3	75	5,000
November	20	80%	7	140	6,550	0	2	30,000	25	500	500	3	60	5,000
December	20	80%	7	140	6,550	0	2	30,000	25	500	500	3	60	5,000
Total	236			2,255			24			5,900			708	

continued

Catch			Total cost (Rp)	Total Revenue (Rp)	Seller (Rp)	Profit/month (Rp)			
Catch/trip (kg)	Catch/month (kg)	Fish price (Rp)				Fishing vessel	Owner	Fisher	Worker
16	17	18	19	20	21	22	23	24	25
20	320	24,000	1,789,000	7,680,000	768,000	4,777,400	1,592,467	1,592,467	345,600
20	450	24,000	2,727,500	10,800,000	1,080,000	6,506,500	2,168,833	2,168,833	486,000
30	675	24,000	2,727,500	16,200,000	1,620,000	11,123,500	3,707,833	3,707,833	729,000
20	450	24,000	2,727,500	10,800,000	1,080,000	6,506,500	2,168,833	2,168,833	486,000
20	320	25,000	2,182,000	8,000,000	800,000	4,658,000	1,552,667	1,552,667	360,000
5	42	26,000	1,073,400	1,092,000	109,200	-139,740	-46,580	-46,580	49,140
20	168	26,000	1,073,400	4,368,000	436,800	2,661,240	887,080	887,080	196,560
5	42	26,000	916,200	1,092,000	109,200	17,460	5,820	5,820	49,140
5	80	25,000	1,789,000	2,000,000	200,000	-79,000	-26,333	-26,333	90,000
30	675	26,000	1,908,750	17,550,000	1,755,000	13,096,500	4,365,500	4,365,500	789,750
30	480	26,000	1,527,000	12,480,000	1,248,000	9,143,400	3,047,800	3,047,800	561,600
30	480	24,000	1,527,000	11,520,000	1,152,000	8,322,600	2,774,200	2,774,200	518,400
	4,182		21,968,250	103,582,000	10,358,200	66,594,360	22,198,120	22,198,120	4,661,190

Note: the same procedure is applied for optimistic and pessimistic scenarios.

C. Result

1. Monthly profit received by shareholders (£)

Month	Common				Range Max				Range Min			
	Owner	Fisher/skipper	Worker	Seller	Owner	Fisher/skipper	Worker	Seller	Owner	Fisher/skipper	Worker	Seller
January	96	96	21	46	17	17	3	6	17	17	3	6
February	131	131	29	65	21	21	3	7	21	21	3	7
March	224	224	44	98	31	31	5	11	31	31	5	11
April	131	131	29	65	21	21	3	7	21	21	3	7
May	94	94	22	48	17	17	3	6	17	17	3	6
June	-3	-3	3	7	3	3	0	1	3	3	0	1
July	54	54	12	26	11	11	2	4	11	11	2	4
August	0	0	3	7	3	3	0	1	3	3	0	1
September	-2	-2	5	12	4	4	1	2	4	4	1	2
October	264	264	48	106	34	34	5	12	34	34	5	12
November	184	184	34	75	27	27	4	9	27	27	4	9
December	168	168	31	70	25	25	4	9	25	25	4	9
Total	**1,341**	**1,341**	**282**	**626**	**212**	**212**	**33**	**74**	**212**	**212**	**33**	**74**

2. Profit analysis (£)

Component	Value	Percentage	Range	
			Max	Min
Total revenue	6,257	100%	743	743
Supplies cost	-1,327	21%	0	0
Selling cost	-626	10%	74	74
Personnel cost	-2,963	47%	457	457
Owner's Profit	1,341	21%	212	212
Fisher	1,341	21%	212	212

3 Profit and expenditure (£)

Shareholder	Profit	Annual CAPEX	Annual OPEX-maintenance	Range	
				Max	Min
Owner	1,341	-226	-66	212	212
Fisher/skipper	1,341	0	0	212	212
Worker	282	0	0	33	33
Seller	626	0	0	74	74

Note: Maximum and minimum ranges are obtained from optimistic and pessimistic scenarios

4. LF vessel

A. Data input

1. Fishing pattern

Month	Trip	Fuel	Catch/trip	Fish Price
January	Low	Peak	Low	Peak
February	Low	Moderate	Low	Moderate
March	Moderate	Low	Low	Peak
April	Low	Moderate	Low	Peak
May	Moderate	Peak	Low	Low
June	Moderate	Low	Low	Moderate
July	Peak	Low	Moderate	Moderate
August	Peak	Low	Peak	Low
September	Peak	Low	Peak	Low
October	Peak	Moderate	Peak	Peak
November	Moderate	Peak	Peak	Low
December	Low	Peak	Moderate	Low

2. Input variables

Variable	Peak	Moderate	Low
Ferry			
Fishing days (day/month)	24	18	12
Successful trip (%)	90%	80%	70%
Optimistic	100%	90%	80%
Pessimistic	80%	70%	60%
Fuel/trip (litre)	30	25	20
Fuel price	5,150	5,150	5,150
Number of platforms	10		
Platform			
Fishing days (day/month)	24	18	12
Successful trip (%)	90%	80%	70%
Optimistic	100%	90%	80%
Pessimistic	80%	70%	60%
Fuel/trip (litre)	8	8	8
Fuel price (Rp)	6,550	6,550	6,550
Lubricant/trip (litre)	0	0	0
Lubricant price (Rp)	30,000	30,000	30,000
Catch/trip (kg)	100	40	20
Fish price (Rp/kg)	8,500	6,500	5,500
Number of fishers/platform	1		
Currency converter (Rp)	16,555		

3. Sharing system

Shareholder	Percentage
Seller	10%
Platform*	75%
Ferry*	25%
Fisher**	50%
Skipper**	25%

*The percentage from 100% net revenue (after deducted by 10% for the seller)
**The percentage from 100% net revenue (after deducted by supplies cost)

B. Profit calculation

1. Common

Month	General			Diesel Fuel			Petrol fuel/Platform			Lubricant/Platform		
	Trip	Successful trip platform (%)	Successful trip ferry (%)	Fuel/trip (litre)	Fuel/month (litre)	Fuel price (Rp)	Fuel/trip (litre)	Fuel/month (litre)	Fuel price	Lubricant/ trip (litre)	Lubricant /month (litre)	Lubricant price (Rp)
1	2	3	4	5	6	7	8	9	10	11	12	13
January	12	70%	70%	30	360	5,150	8	96	6,550	0	3	30,000
February	12	70%	70%	25	300	5,150	8	96	6,550	0	3	30,000
March	18	80%	70%	20	360	5,150	8	144	6,550	0	5	30,000
April	12	70%	70%	25	300	5,150	8	96	6,550	0	3	30,000
May	18	80%	70%	30	540	5,150	8	144	6,550	0	5	30,000
June	18	80%	70%	20	360	5,150	8	144	6,550	0	5	30,000
July	24	90%	80%	20	480	5,150	8	192	6,550	0	6	30,000
August	24	90%	90%	20	480	5,150	8	192	6,550	0	6	30,000
September	24	90%	90%	20	480	5,150	8	192	6,550	0	6	30,000
October	24	90%	90%	25	600	5,150	8	192	6,550	0	6	30,000
November	18	80%	90%	30	540	5,150	8	144	6,550	0	5	30,000
December	12	70%	80%	30	360	5,150	8	96	6,550	0	3	30,000
Total	216				5,160			1,728			58	

Continued

Total Catch (Rp)	Total fuel (Rp)	Total cost (Rp)	Total revenue (Rp)	Profit (Rp)				
				Revenue from platform	Revenue from ferry	Fishers share	Skipper share	Profit
14	15	16	17	18	19	20	21	22
1,176	1,320	9,102,000	9,996,000	6,747,300	2,249,100	-250,350	98,775	45,975
1,176	1,260	8,793,000	7,644,000	5,159,700	1,719,900	-1,044,150	43,725	-912,975
2,016	1,800	12,726,000	17,136,000	11,566,800	3,855,600	347,400	500,400	1,848,600
1,176	1,260	8,793,000	9,996,000	6,747,300	2,249,100	-250,350	176,025	277,725
2,016	1,980	13,653,000	11,088,000	7,484,400	2,494,800	-1,693,800	-71,550	-1,908,450
2,016	1,800	12,726,000	13,104,000	8,845,200	2,948,400	-1,013,400	273,600	-192,600
6,912	2,400	16,968,000	44,928,000	30,326,400	10,108,800	7,915,200	1,909,200	13,642,800
19,440	2,400	16,968,000	106,920,000	72,171,000	24,057,000	28,837,500	5,396,250	45,026,250
19,440	2,400	16,968,000	106,920,000	72,171,000	24,057,000	28,837,500	5,396,250	45,026,250
19,440	2,520	17,586,000	165,240,000	111,537,000	37,179,000	48,520,500	8,522,250	74,087,250
12,960	1,980	13,653,000	71,280,000	48,114,000	16,038,000	18,621,000	3,314,250	28,563,750
2,688	1,320	9,102,000	14,784,000	9,979,200	3,326,400	1,365,600	368,100	2,469,900
90,456	22,440	157,038,000	579,036,000	390,849,300	130,283,100	130,192,650	25,927,275	207,974,475

Note: the same procedure is applied for optimistic and pessimistic scenarios.

C. Result

1. Monthly profit received by shareholders (£)

Month	Common				Optimistic				Pessimistic			
	Owner	Fisher	Skipper	Seller	Owner	Fisher	Skipper	Seller	Owner	Fisher	Skipper	Seller
January	3	7	6	60	94	4	10	18	81	4	9	16
February	-55	0	3	46	72	3	8	14	62	3	7	12
March	112	17	30	104	150	6	17	30	131	6	15	26
April	17	7	11	60	94	4	10	18	81	4	9	16
May	-115	-1	-4	67	97	4	11	19	85	4	9	17
June	-12	5	17	79	114	5	13	23	100	5	11	20
July	824	71	115	271	343	13	38	68	305	13	34	60
August	2,720	198	326	646	767	27	85	151	686	27	76	136
September	2,720	198	326	646	767	27	85	151	686	27	76	136
October	4,475	331	515	998	1,185	42	132	234	1,061	42	118	209
November	1,725	129	200	431	545	20	61	108	484	20	54	96
December	149	16	22	89	129	5	14	26	113	5	13	22
Total	**12,563**	**979**	**1,566**	**3,498**	**4,357**	**160**	**484**	**861**	**3,876**	**160**	**431**	**766**

2. Profit analysis (£)

Component	Value	Percentage	Range	
			Max	Min
Total revenue	34,977	100%	8,605	7,656
Supplies cost	-9,486	27%	0	0
Selling cost	-3,498	10%	861	766
Personnel cost	-9,430	27%	3,388	3,015
Owner's Profit	12,563	36%	4,357	3,876
Skipper	1,566	20%	484	431

3 Profit and expenditure (£)

Shareholder	Profit	Annual CAPEX	Annual OPEX-maintenance	Range	
				Max	Min
Fishing unit owner	12,563	-2,628	-2,966	4,357	3,876
Skipper	1,566	0	0	484	431
Fisher	979	0	0	160	160
Seller	3,498	0	0	861	766

Note: Maximum and minimum ranges are obtained from optimistic and pessimistic scenarios

Appendix H. One-day observation record

Vessel's name	: PD vessel		
Fuel provision	: 90 litre		
Number of fishers	: 11 people		
Departure time	: 05:30		
Arrival time	: 17:53		
Fuel consumption	: 85 litre		
Total catch	: 185	Kg	
Total revenue	: 2.000.000	IDR	
Date	: 26 September 2015		

Operation phase	Duration (minute)	Main Engine	Power	Speed	
				kmh	knots
Start 05.30 am					
Loading	00:15:42	off	off	0.00	0.00
Manoeuvring	00:01:40	on	25%	2.80	1.51
Steaming	00:10:49	on	75%	11.60	6.26
Setting	00:05:13	on	50%	8.60	4.64
Hauling	00:17:03	off	off	0.00	0.00
Steaming	02:05:00	on	75%	13.30	7.18
Setting	00:05:30	on	50%	10.30	5.56
Hauling	00:16:22	off	off	0.00	0.00
Steaming	00:43:20	on	50%	9.90	5.35
Setting	00:05:21	on	50%	9.20	4.97
Hauling	00:16:22	off	off	0.00	0.00
Steaming	01:20:27	on	75%	11.20	6.05
Setting	00:05:19	on	50%	8.80	4.75
Hauling	00:16:10	off	off	0.00	0.00
Steaming	01:24:08	on	75%	12.80	6.91
Anchoring/Break	00:45:58	off	off	0.00	0.00
Steaming	03:54:20	on	100%	13.80	7.45
Manoeuvring	00:01:37	on	25%	3.10	1.67
Unloading	00:10:03	off	off	0.00	0.00
Manoeuvring	00:01:51	on		2.90	1.57
Finish 17.53 pm					
Total fishing time	**12:22:15**				

Vessel's name : TN vessel (active operation)
Fuel provision : 20 litre
Number of fishers : 3 people
Departure time : 05:00
Arrival time : 17:03
Fuel consumption : 17 litre
Total catch : 23 Kg
Total revenue : 1.150.000 IDR
Date : 27 January 2016

Operation phase	**Duration (minute)**	**Main Engine**	**Power**	**Speed**	
				kmh	**knots**
Start 05.30 am					
Berthing	00:20:08	off	off	0.00	0.00
Manoeuvring	00:02:15	on	25%	3.40	1.84
Steaming	00:45:00	on	100%	11.70	6.32
Fish locating	00:13:00	on	75%	9.50	5.13
Setting the gear	00:07:25	on	25%	4.40	2.38
Encircling the gear	00:45:50	on	50%	6.34	3.42
Hauling the gear	01:17:00	off	off	0.00	0.00
Fish locating	00:23:00	on	75%	8.70	4.70
Setting the gear	00:07:55	on	25%	4.42	2.39
Encircling the gear	00:46:39	on	50%	5.80	3.13
Hauling the gear	01:12:00	off	off	0.00	0.00
Fish locating	00:15:30	on	75%	10.10	5.45
Setting the gear	00:06:48	on	25%	4.45	2.40
Encircling the gear	00:40:54	on	50%	6.70	3.62
Hauling the gear	01:20:00	off	off	0.00	0.00
Fish locating	00:08:30	on	75%	8.10	4.37
Setting the gear	00:06:40	on	25%	3.54	1.91
Encircling the gear	00:46:37	on	50%	7.15	3.86
Hauling the gear	01:11:00	off	off	0.00	0.00
Steaming	01:00:22	on	100%	12.30	6.64
Manoeuvring	00:02:02	on	25%	3.90	2.11
Unloading	00:10:00	off	off	0.00	0.00
Finish 17.03 pm					
Total fishing time	**11:48:35**				

Vessel's name	: TN vessel (passive operation)		
Fuel provision	: 15 litre		
Number of fishers	: 3 people		
Departure time	: 05:10		
Arrival time	: 08:18		
Fuel consumption	: 7 litre		
Total catch	: 4	Kg	
Total revenue	: 150.000	IDR	
Date	: 30 September 2015		

Operation phase	Duration (minute)	Main Engine	Power	Speed	
				kmh	knots
Start 05.10 am					
Loading	00:15:04	off	off	0.00	0.00
Manoeuvring	00:01:23	on	25%	3.40	1.84
Steaming	00:40:07	on	100%	11.70	6.32
Hauling the gear	01:16:20	off	off	0.00	0.00
Setting the gear*	00:07:12	on	25%	4.81	2.60
Steaming	00:35:53	on	100%	12.30	6.64
Manoeuvring	00:02:37	on	25%	3.20	1.73
Unloading	00:10:00				
Finish 08.18 am					
Total fishing time	**03:08:36**				

* The gear is soaked for 24 hours and hauled the next day.

Vessel's name : HL vessel
Fuel provision : 4 litre
Number of fishers : 1 person
Departure time : 15:00
Arrival time : 06:05
Fuel consumption : 3.5 litre
Total catch : 15 Kg
Total revenue : 120.000 IDR
Date : 24 September 2015

Operation phase	Duration (minute)	Main Engine	Power	Speed	
				kmh	knots
Start 15.00 pm					
Loading	00:42:38	off	off	0.00	0.00
Manoeuvring	00:03:45	off	off	0.00	0.00
Steaming	00:39:42	on	100%	11.90	6.43
Anchoring	12:32:13	off	off	0.00	0.00
Steaming	00:45:22	on	100%	11.40	6.16
Manoeuvring	00:02:44	off	off	0.00	0.00
Unloading	00:04:29	off	0%	0.00	0.00
Manoeuvring	00:02:44	off	off	0.00	0.00
Finish 05.53 am					
Total fishing time	**14:53:37**				

Vessel's name : LF vessel
Platforms : 10
Fuel provision : 20 litre (ferry) and 7-8 litre/platform
Number of fishers : 2 persons (ferry) and 17 persons (platforms)

Alighting operation

Departure time : 14:50
Arrival time : 17:02

Picking operation

Departure time : 05:30
Arrival time : 17:53
Fuel consumption : 17 litre
Total catch : 1.492 Kg
Total revenue : 7.850.000 IDR
Date : 22-23 September 2015

Operation phase	Duration (minute)	Main Engine	Power	Speed	
				kmh	knot
Alighting operation started 14.50 pm					
Manoeuvring	00:02:40	on	25%	2.90	1.57
Loading	00:40:25	off	off	0.00	0.00
Manoeuvring	00:01:37	on	25%	3.10	1.67
Steaming	00:06:52	on	50%	9.30	5.02
Alighting	00:01:10	on	0%	0.00	0.00
Steaming	00:02:52	on	25%	3.50	1.89
Alighting	00:01:15	on	0%	0.00	0.00
Steaming	00:01:42	on	25%	4.20	2.27
Alighting	00:00:55	on	0%	0.00	0.00
Steaming	00:03:08	on	50%	7.80	4.21
Alighting	00:01:08	on	0%	0.00	0.00
Steaming	00:01:57	on	25%	5.80	3.13
Alighting	00:01:03	on	0%	0.00	0.00
Steaming	00:03:21	on	25%	4.90	2.65
Moving the lift net	00:07:38	on	100%	5.20	2.81
Alighting	00:00:51	on	0%	0.00	0.00
Steaming	00:04:41	on	50%	9.50	5.13
Alighting	00:01:02	on	0%	0.00	0.00
Steaming	00:01:23	on	25%	5.00	2.70
Alighting	00:00:40	on	0%	0.00	0.00
Steaming	00:01:39	on	25%	4.20	2.27
Alighting	00:00:54	on	0%	0.00	0.00
Steaming	00:04:08	on	50%	9.10	4.91
Moving the lift net	00:11:48	on	100%	5.80	3.13

Operation phase	Duration (minute)	Main Engine	Power	Speed	
				kmh	knot
Alighting	00:01:02	on	0%	0.00	0.00
Steaming	00:15:11	on	75%	12.90	6.97
Manoeuvring	00:01:50	on	25%	3.30	1.78
Finish 16.53 pm					
Lift net operation	11:41:11	off	off	0.00	0.00
Picking operation started 05.10 am					
Manoeuvring	00:02:32	on	25%	3.10	1.67
Steaming	00:07:32	on	50%	8.70	4.70
Boarding	00:01:50	on	0%	0.00	0.00
Steaming	00:01:45	on	25%	3.30	1.78
Boarding	00:02:15	on	0%	0.00	0.00
Steaming	00:00:53	on	25%	4.40	2.38
Boarding	00:02:11	on	0%	0.00	0.00
Steaming	00:04:54	on	25%	4.80	2.59
Boarding	00:02:28	on	0%	0.00	0.00
Steaming	00:01:57	on	50%	7.70	4.16
Boarding	00:01:08	on	0%	0.00	0.00
Steaming	00:03:07	on	25%	4.80	2.59
Boarding	00:01:55	on	0%	0.00	0.00
Steaming	00:05:01	on	50%	8.90	4.81
Boarding	00:02:36	on	0%	0.00	0.00
Steaming	00:01:40	on	25%	4.60	2.48
Boarding	00:00:53	on	0%	0.00	0.00
Steaming	00:01:03	on	50%	8.20	4.43
Boarding	00:01:24	on	0%	0.00	0.00
Steaming	00:03:58	on	50%	8.60	4.64
Boarding	00:02:03	on	0%	0.00	0.00
Steaming	00:17:09	on	75%	11.80	6.37
Manoeuvring	00:02:37	on	25%	3.50	1.89
Unloading	00:07:41	off	Off	0.00	0.00
Manoeuvring	00:02:02	on		3.01	1.63
Finish 06.33 am					
Total fishing time	**15:30:17**				

Appendix I. Inventory analysis for LCA

1. PD vessel

<table>
<tr><th rowspan="2">Operation</th><th rowspan="2">Assembly</th><th rowspan="2">Resources</th><th rowspan="2">Unit</th><th rowspan="2">Input</th><th rowspan="2">Lifetime/ Frequency</th><th colspan="3">Waste Treatment</th></tr>
<tr><th>Incinerated</th><th>Landfill</th><th>Reuse</th></tr>
<tr><td>1) Production</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">Fishing vessel</td><td rowspan="2">Hull</td><td>Sawn wood</td><td>kg</td><td>7,500</td><td rowspan="8">20 years</td><td rowspan="8">30%</td><td rowspan="8">20%</td><td rowspan="8">50%</td></tr>
<tr><td>Reinforcing steel</td><td>kg</td><td>220</td></tr>
<tr><td rowspan="5">Painting</td><td>Polyvinyl Acetate</td><td>kg</td><td>5</td></tr>
<tr><td>White cement</td><td>kg</td><td>7</td></tr>
<tr><td>Talc Powder</td><td>kg</td><td>5</td></tr>
<tr><td>Alkyd paint</td><td>kg</td><td>11</td></tr>
<tr><td>Antifouling</td><td>kg</td><td>5</td></tr>
<tr><td>Electricity</td><td>Electricity</td><td>kWh</td><td>290</td></tr>
<tr><td>Engine</td><td>Marine outboard engine</td><td>Yamaha E40GMHL, 40 HP</td><td>unit</td><td>1</td><td>7 years</td><td></td><td></td><td>100%</td></tr>
<tr><td rowspan="3">Fishing gear</td><td rowspan="2">Net</td><td>Polyamide (Nylon)</td><td>kg</td><td>144</td><td rowspan="3">10 years</td><td rowspan="3"></td><td rowspan="3">80%</td><td rowspan="3">20%</td></tr>
<tr><td>Natural Dye</td><td>litre</td><td>100</td></tr>
<tr><td>Sinker</td><td>Lead</td><td>kg</td><td>17.5</td></tr>
<tr><td>Fish container</td><td>Plastic container</td><td>Plastic container 200 litres</td><td>kg</td><td>38</td><td>5 years</td><td></td><td>20%</td><td>80%</td></tr>
<tr><td>Fuel container</td><td>Plastic container</td><td>Plastic container 35 litres</td><td>kg</td><td>4.5</td><td>5 years</td><td></td><td>20%</td><td>80%</td></tr>
<tr><td>2) Operation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Supplies</td><td>Petrol</td><td>Petrol</td><td>kg</td><td>16,494</td><td rowspan="3">1 year</td><td colspan="3" rowspan="3">n/a</td></tr>
<tr><td>Lubricant</td><td>Lubricating oil</td><td>kg</td><td>655</td></tr>
<tr><td>Ice</td><td>Ice block</td><td>kg</td><td>13,734</td></tr>
<tr><td>3) Maintenance</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="9">Fishing vessel</td><td rowspan="3">Hull</td><td>Sawn wood</td><td>kg</td><td>750</td><td rowspan="3">Every 2 years</td><td rowspan="9">50%</td><td rowspan="9">50%</td><td rowspan="9"></td></tr>
<tr><td>Reinforcing steel</td><td>kg</td><td>22</td></tr>
<tr><td>Electricity</td><td>kWh</td><td>72</td></tr>
<tr><td rowspan="6">Repainting</td><td>Polyvinyl Acetate</td><td>kg</td><td>5</td><td rowspan="6">Every 3 months</td></tr>
<tr><td>White cement</td><td>kg</td><td>7</td></tr>
<tr><td>Talc Powder</td><td>kg</td><td>5</td></tr>
<tr><td>Alkyd paint</td><td>kg</td><td>6</td></tr>
<tr><td>Antifouling</td><td>kg</td><td>5</td></tr>
<tr><td>Electricity</td><td>kWh</td><td>3.6</td></tr>
<tr><td>Engine</td><td>Oil changing</td><td>Lubricating oil</td><td>kg</td><td>0.445</td><td>Every week</td><td colspan="3">n/a</td></tr>
<tr><td rowspan="7">Fishing gear</td><td rowspan="2">Net</td><td>Polyamide (Nylon)</td><td>kg</td><td>12</td><td>Every year</td><td rowspan="7"></td><td rowspan="7">70%</td><td rowspan="7">30%</td></tr>
<tr><td>Natural Dye</td><td>litre</td><td>100</td><td>Every 3 weeks</td></tr>
<tr><td rowspan="3">Ropes</td><td>Polyethylene, HDPE</td><td>kg</td><td>27</td><td rowspan="3">Every 5 years</td></tr>
<tr><td>Polyethylene, HDPE</td><td>kg</td><td>3.4</td></tr>
<tr><td>Polyethylene, HDPE</td><td>kg</td><td>7</td></tr>
<tr><td rowspan="2">Floats</td><td>Bamboo</td><td>kg</td><td>80</td><td>Every year</td></tr>
<tr><td>Plastic container 35 litres</td><td>kg</td><td>1.5</td><td>Every 5 years</td></tr>
</table>

2. TN vessel

Operation	Assembly	Resources	Unit	Input	Lifetime/ Frequency	Waste Treatment		
						Incinerated	Landfill	Reuse
1) Production								
Fishing vessel	Hull	Sawn wood	kg	4,500	20 years	30%	20%	50%
		Reinforcing steel	kg	150				
	Painting	Polyvinyl Acetate	kg	3				
		White cement	kg	5				
		Talc Powder	kg	3				
		Alkyd paint	kg	10				
		Antifouling	kg	4				
	Electricity	Electricity	kWh	220				
Engine	Marine diesel engine	Dongfeng S1115, 24 HP	pcs	1	3 years			100%
Fishing gear	Net	Polyamide (Nylon)	kg	1	10 years		1%	99%
	Sinker	Lead	kg	36				
Fish container	EPS cool boxes	Cool box EPS insulation board	kg	1	1 month		30%	70%
Fuel container	Plastic container	Plastic container 35 litres	kg	6	5 years		20%	80%
2) Operation								
Supplies	Diesel fuel	Diesel	kg	3,507	1 year	n/a		
	Ice	Ice block	kg	6,025				
3) Maintenance								
Fishing vessel	Hull	Sawn wood	kg	450	Every 2 years	50%	50%	
		Reinforcing steel	kg	15				
		Electricity	kWh	50				
	Repainting	Polyvinyl Acetate	kg	3	Every 3 months			
		White cement	kg	5				
		Talc Powder	kg	3				
		Alkyd paint	kg	4				
		Antifouling	kg	2				
		Electricity	kWh	3.6				
Engine	Oil changing	Lubricating oil	kg	4	Every 3 months	n/a		
		Diesel	kg	2.5				
Fishing gear	Net	Polyamide (Nylon)	kg	2	Every year		100%	
	Rope	Polyethylene, HDPE	kg	23.6	Every 5 years			
		Polypropylene	kg	20				
	Floats	Synthetic rubber	kg	1.4	Every year			
		Plastic container 35 litres	kg	3	Every 5 years			

3. HL vessel

Operation	Assembly	Resources	Unit	Input	Lifetime/ Frequency	Waste Treatment		
						Incinerated	Landfill	Reuse
1) Production								
Fishing vessel	Hull	Fibreglass	kg	350	20 years	30%	70%	
		Sawn wood	kg	187.5				
		Reinforcing steel	kg	5				
	Painting	Antifouling	kg	3				
	Electricity	Electricity	kWh	40				
Engine	Multipurpose engine	Yamaha MZ175, 4.7 HP	pcs	2	5 years			100%
	Generator	Yamaha ET-1, 780 watts/220v	pcs	1	5 years			100%
Fishing gear	Mainline	Polyamide (Nylon)	kg	1.6	10 years		80%	20%
	Sinker	Lead	kg	1				
	Roller	Polypropylene	kg	1.6				
Fish container	EPS cool boxes	Cool box EPS insulation board	kg	1	1 month	30%		70%
Fuel container	Plastic container	Plastic container 10 litres	kg	0.5	5 years		20%	80%
Lamps	Compact fluorescent lamp	Compact fluorescent lamp	kg	0.75	4 years		100%	
2) Operation								
Supplies	Petrol	Petrol	kg	1,684	1 year	n/a		
	Lubricant	Lubricating oil	kg	21				
	Ice	Ice block	kg	5,900				
3) Maintenance								
Fishing vessel	Hull	Fibreglass	kg	15	Every 3 years	30%	70%	
		Sawn wood	kg	56.25				
		Reinforcing steel	kg	0.5				
		Electricity	kWh	7.2				
	Repainting	Antifouling	kg	3				
Engine	Oil changing	Lubricating oil	kg	0.89	Every month	n/a		
Fishing gear	Branchline	Polyamide (Nylon)	kg	2.4	Every year		100%	
	Hook and Swivel	Steel, low-alloyed	kg	0.09	Every year			

4. LF vessel

Operation	Assembly	Resources	Unit	Input	Lifetime/ Frequency	Waste Treatment		
						Incinerated	Landfill	Reuse
1) Production								
Fishing vessel	Hull	Sawn wood	kg	9,000	20 years	30%	20%	50%
		Reinforcing steel	kg	250				
	Painting	Polyvinyl Acetate	kg	7				
		White cement	kg	9				
		Talc Powder	kg	7				
		Alkyd paint	kg	19				
		Antifouling	kg	7				
	Electricity	Electricity	kWh	300				
Engine	Marinised diesel engine	Mitsubishi 4D31, 100 HP	pcs	1	10 years			100%
Fishing gear	Bamboo platform	Bamboo	kg	3,635	10 years	49.20%	10.80%	40%
		Polypropylene	kg	90				
	Net	Polypropylene	kg	50	3 years		50%	50%
		Polyethylene, HDPE	kg	15				
		Polypropylene	kg	15				
	Generator set	Sumura, 1000 watts/220v	unit	1	5 years			100%
	Platform base	Plastic container 200 litres	kg	136.80	3 years		20%	80%
Fish container	Bamboo basket	Bamboo	kg	20	1 year	90%	10%	
Fuel container	Plastic container	Plastic container 200 litres	kg	7.60	5 years		20%	80%
Lamps	Compact fluorescent lamp	Compact fluorescent lamp	kg	1.88	4 years		100%	
2) Operation								
Supplies for ferry	Diesel fuel	Diesel	kg	4,319	n/a	n/a		
Supplies for platform	Petrol	Petrol	kg	1,291				
	Lubricant	Lubricating oil	kg	52				
3) Maintenance								
Fishing vessel	Hull	Sawn wood	kg	900	Every 2 years	50%	50%	
		Reinforcing steel	kg	27				
		Electricity	kWh	72				
	Repainting	Polyvinyl Acetate	kg	7	Every 4 months			
		White cement	kg	9				
		Talc Powder	kg	7				
		Alkyd paint	kg	8				
		Antifouling	kg	4				
		Electricity	kWh	4				
Engine	Oil changing	Lubricating oil	kg	10.70	Every month	n/a		
Fishing gear	Bamboo platform	Bamboo	kg	910	Every 2.5 years	88.40%	11.60%	
		Polypropylene	kg	50				

Appendix J. LCA result

1. PD vessel

a. Characterisation (midpoint result)

Life stage	Fishing attributes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1) Production	Fishing vessel	2.64	1.73	0.42	564.66	0.00	0.12	6,803.49	2,298.54	1.85	156.24	0.45	0.03	81.48	1,110.64	14.58
	Fishing gear	1.40	3.72	0.04	1,551.58	0.00	0.05	42,414.96	971.85	1.14	0.13	0.27	0.02	99.24	2,517.18	5.50
	Fish container	3.02	3.41	0.02	0.00	0.00	0.00	46.09	0.14	0.34	0.00	0.12	0.00	21.03	768.86	0.00
	Fuel container	0.36	0.40	0.00	0.00	0.00	0.00	5.46	0.02	0.04	0.00	0.01	0.00	2.49	91.05	0.00
	Lamps	n/a														
2) Use - supplies	Fuel	3,061.76	149.88	17.57	430,079.14	0.01	17.47	2,293,329.20	504,890.94	280.42	111.62	110.28	5.16	12,350.37	989,565.01	279.71
	Lubricant	13.12	11.12	1.12	26,183.02	0.00	4.66	130,805.19	30,389.02	15.80	10.12	5.89	0.35	682.28	53,445.32	50.74
	Ice	25.01	6.23	29.18	2,619.22	0.00	0.16	51,365.52	14,220.36	29.15	2.89	8.35	0.78	1,600.50	19,411.55	18.23
3) Use - Maintenance	Fishing vessel	19.78	13.41	1.55	2,024.69	0.00	0.40	97,776.43	12,216.04	9.17	199.34	2.91	0.33	376.05	6,594.59	121.76
	Engine	0.46	0.39	0.04	925.00	0.00	0.16	4,621.12	1,073.59	0.56	0.36	0.21	0.01	24.10	1,888.13	1.79
	Fishing gear	0.54	3.22	0.09	1,244.71	0.00	0.06	49,108.81	524.68	3.17	0.01	0.67	0.02	121.75	2,335.17	0.66
4) End of life	Fishing vessel	0.10	0.44	0.03	227.86	0.00	0.07	266.99	424.73	1.21	0.00	0.23	0.03	204.32	360.28	-3.57
	Fishing gear	0.01	0.02	0.01	29.43	0.00	0.02	56.31	86.55	0.22	0.00	0.05	0.02	51.06	94.98	0.01
	Fish container	0.00	0.00	0.00	0.53	0.00	0.00	3.31	3.70	0.00	0.00	0.00	0.00	0.10	1.70	0.00
	Fuel container	0.00	0.00	0.00	0.06	0.00	0.00	0.39	0.44	0.00	0.00	0.00	0.00	0.01	0.20	0.00
	Lamps	n/a														

Note: 1. Carcinogen (kg C_2H_3Cl eq); 2. Non-carcinogen (kg C_2H_3Cl eq); 3. Respiratory inorganic (kg $PM_{2.5}$ eq); 4. Ionizing radiations (Bq C-14 eq); 5. Ozone layer depletion (kg CFC-11 eq); 6. Respiratory organics (kg C_2H_4 eq); 7. Aquatic ecotoxicity (kg TEG water); 8. Teresstrial ecotoxicity (kg TEG soil); 9. Terrestrial acidification/nitrification (kg SO_2 eq); 10. Land occupation (m^2org.arable); 11. Aquatic acidification (kg SO_2 eq); 12. Aquatic eutropication (kg PO_4 P-lim); 13. Global warming (kg CO_2 eq); 14. Non-renewable energy (MJ primary); 15. Mineral extraction (MJ surplus)

b. Damage assessment (endpoint result)

Life stage		Human health	Ecosystem Quality	Climate change	Resources use	Total
		mPt	mPt	mPt	mPt	mPt
1) Production	Fishing vessel	43.40	13.90	8.23	7.40	72.93
	Fishing gear	6.20	0.57	8.23	11.75	26.75
	Fish container	4.43	0.03	2.12	5.06	11.64
	Fuel container	0.52	0.00	0.25	0.60	1.38
	Lamps	-	-	-	-	-
2) Use - supplies	Fuel	3,020.00	330.00	1,250.00	6,510.00	11,110.00
	Lubricant	122.00	20.00	68.90	352.00	562.90
	Ice	2,890.00	10.80	162.00	128.00	3,190.80
3) Use - Maintenance	Fishing vessel	165.68	23.99	37.97	44.20	271.84
	Engine	4.32	0.71	2.43	12.40	19.86
	Fishing gear	10.57	0.97	14.02	20.02	45.57
4) End of life	Fishing vessel	3.18	0.34	20.62	2.35	26.49
	Fishing gear	0.62	0.07	5.15	0.62	6.47
	Fish container	0.01	2.26	0.01	0.01	2.29
	Fuel container	0.00	0.00	0.00	0.00	0.00
	Lamps	-	-	-	-	-
	Total	6,270.94	403.63	1,579.93	7,094.42	15,348.92

2. TN vessel

a. Characterisation (midpoint result)

Life stage	Fishing attributes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1) Production	Fishing vessel	1.77	1.16	0.30	360.25	0.00	0.08	4,864.85	1,482.73	1.21	94.08	0.30	0.02	54.38	732.95	9.99
	Fishing gear	1.27	2.53	0.01	151.27	0.00	0.01	3,964.87	407.95	0.26	0.10	0.08	0.01	16.64	524.15	4.53
	Fish container	0.02	1.46	0.05	0.00	0.00	0.22	8,952.39	6.94	0.96	0.00	0.40	0.00	47.95	1,424.72	0.00
	Fuel container	0.48	0.54	0.00	0.00	0.00	0.00	7.28	0.02	0.05	0.00	0.02	0.00	3.32	121.40	0.00
	Lamps	n/a														
2) Use - supplies	Fuel	26.85	28.04	2.93	88,404.24	0.00	2.72	464,679.78	102,515.26	49.19	21.33	18.83	1.04	1,836.13	200,571.79	36.44
	Lubricant	n/a														
	Ice	10.97	2.73	12.80	1,149.03	0.00	0.07	22,533.66	6,238.36	12.79	1.27	3.66	0.34	702.13	8,515.70	8.00
3) Use - Maintenance	Fishing vessel	11.91	6.27	1.12	1,228.22	0.00	0.25	58,659.07	5,517.15	5.59	122.28	1.73	0.17	243.47	4,032.91	54.33
	Engine	0.40	0.35	0.04	891.66	0.00	0.12	4,520.25	1,034.64	0.53	0.31	0.20	0.01	21.90	1,877.45	1.34
	Fishing gear	1.58	3.14	0.02	187.90	0.00	0.02	4,924.78	506.72	0.32	0.13	0.10	0.01	20.67	651.05	5.63
4) End of life	Fishing vessel	0.06	0.27	0.02	122.55	0.00	0.04	82.42	146.25	0.76	0.00	0.14	0.02	124.95	249.02	-0.95
	Fishing gear	0.00	0.00	0.00	2.68	0.00	0.00	25.62	26.24	0.01	0.00	0.00	0.01	1.13	8.66	0.00
	Fish container	0.00	0.00	0.00	1.25	0.00	0.00	7.83	8.76	0.00	0.00	0.00	0.00	0.23	4.02	0.00
	Fuel container	0.00	0.00	0.00	0.08	0.00	0.00	0.52	0.58	0.00	0.00	0.00	0.00	0.02	0.27	0.00
	Lamps	n/a														

Note: 1. Carcinogen (kg C_2H_3Cl eq); 2. Non-carcinogen (kg C_2H_3Cl eq); 3. Respiratory inorganic (kg $PM_{2.5}$ eq); 4. Ionizing radiations (Bq C-14 eq); 5. Ozone layer depletion (kg CFC-11 eq); 6. Respiratory organics (kg C_2H_4 eq); 7. Aquatic ecotoxicity (kg TEG water); 8. Teresstrial ecotoxicity (kg TEG soil); 9. Terrestrial acidification/nitrification (kg SO_2 eq); 10. Land occupation (m^2org.arable); 11. Aquatic acidification (kg SO_2 eq); 12. Aquatic eutropication (kg PO_4 P-lim); 13. Global warming (kg CO_2 eq); 14. Non-renewable energy (MJ primary); 15. Mineral extraction (MJ surplus)

b. Damage assessment (endpoint result)

Life stage		Human health	Ecosystem Quality	Climate change	Resources use	Total
		mPt	mPt	mPt	mPt	mPt
1) Production	Fishing vessel	31.20	8.45	5.49	4.89	50.03
	Fishing gear	2.84	0.29	1.68	3.48	8.28
	Fish container	5.87	0.11	4.84	9.37	20.19
	Fuel container	0.70	0.00	0.34	0.80	1.84
	Lamps					-
2) Use - supplies	Fuel	315.00	66.30	185.00	1,320.00	1,886.30
	Lubricant					0.00
	Ice	1,270.00	4.76	70.90	56.10	1,401.76
3) Use - Maintenance	Fishing vessel	117.12	13.52	24.59	26.90	182.13
	Engine	3.88	0.68	2.21	12.40	19.17
	Fishing gear	3.52	0.35	2.09	4.32	10.29
4) End of life	Fishing vessel	2.04	0.14	12.62	1.63	16.43
	Fishing gear	0.03	0.02	0.12	0.06	0.22
	Fish container	0.01	0.01	0.02	0.03	0.07
	Fuel container	0.00	0.00	0.00	0.00	0.00
	Lamps					-
	Total	1,752.21	94.63	309.89	1,439.98	3,596.71

3. HL vessel

a. Characterisation (midpoint result)

Life stage	Fishing attributes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1) Production	Fishing vessel	6.59	7.05	0.13	632.39	0.00	0.15	4,453.75	1,215.96	1.29	7.70	0.37	0.02	66.60	1,188.93	4.42
	Fishing gear	0.37	0.66	0.01	527.98	0.00	0.01	14,609.78	272.63	0.34	0.01	0.08	0.01	30.09	688.33	1.16
	Fish container	0.02	1.46	0.05	0.00	0.00	0.22	8,952.39	6.94	0.96	0.00	0.40	0.00	47.95	1,424.72	0.00
	Fuel container	0.04	0.04	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.28	10.12	0.00
	Lamps	0.47	2.12	0.01	43.14	0.00	0.00	1,733.72	265.20	0.10	0.13	0.03	0.02	3.36	47.60	8.27
2) Use - supplies	Fuel	312.60	15.30	1.79	43,910.11	0.00	1.78	234,143.71	51,548.22	28.63	11.40	11.26	0.53	1,260.94	101,032.34	28.56
	Lubricant	0.42	0.36	0.04	839.46	0.00	0.15	4,193.75	974.30	0.51	0.32	0.19	0.01	21.87	1,713.51	1.63
	Ice	10.74	2.68	12.54	1,125.19	0.00	0.07	22,066.15	6,108.93	12.52	1.24	3.59	0.34	687.56	8,339.02	7.83
3) Use - Maintenance	Fishing vessel	1.85	2.28	0.08	199.79	0.00	0.04	2,385.14	809.15	0.48	8.01	0.15	0.02	21.93	395.47	5.67
	Engine	0.21	0.18	0.02	427.72	0.00	0.08	2,136.82	496.43	0.26	0.17	0.10	0.01	11.15	873.08	0.83
	Fishing gear	0.55	0.99	0.02	791.96	0.00	0.02	21,914.67	408.95	0.51	0.02	0.12	0.01	45.13	1,032.49	1.73
4) End of life	Fishing vessel	0.01	0.04	0.00	16.73	0.00	0.01	76.26	65.40	0.11	0.00	0.02	0.01	30.28	44.53	-0.15
	Fishing gear	0.00	0.00	0.00	0.64	0.00	0.00	5.91	7.03	0.00	0.00	0.00	0.00	0.14	2.07	0.00
	Fish container	0.00	0.00	0.00	1.25	0.00	0.00	7.83	8.76	0.00	0.00	0.00	0.00	0.23	4.02	0.00
	Fuel container	0.00	0.00	0.00	0.01	0.00	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.02	0.00
	Lamps	0.00	0.00	0.00	0.05	0.00	0.00	1.46	1.07	0.00	0.00	0.00	0.00	0.08	0.17	0.00

Note: 1. Carcinogen (kg C_2H_3Cl eq); 2. Non-carcinogen (kg C_2H_3Cl eq); 3. Respiratory inorganic (kg $PM_{2.5}$ eq); 4. Ionizing radiations (Bq C-14 eq); 5. Ozone layer depletion (kg CFC-11 eq); 6. Respiratory organics (kg C_2H_4 eq); 7. Aquatic ecotoxicity (kg TEG water); 8. Teresstrial ecotoxicity (kg TEG soil); 9. Terrestrial acidification/nitrification (kg SO_2 eq); 10. Land occupation (m^2org.arable); 11. Aquatic acidification (kg SO_2 eq); 12. Aquatic eutropication (kg PO_4 P-lim); 13. Global warming (kg CO_2 eq); 14. Non-renewable energy (MJ primary); 15. Mineral extraction (MJ surplus)

b. Damage assessment (endpoint result)

Life stage		Human health	Ecosystem Quality	Climate change	Resources use	Total
		mPt	mPt	mPt	mPt	mPt
1) Production	Fishing vessel	18.20	1.43	6.73	7.85	34.21
	Fishing gear	0.09	0.01	0.18	0.27	0.56
	Fish container	5.87	0.11	4.84	9.37	20.19
	Fuel container	0.06	0.00	0.03	0.07	0.15
	Lamps	1.87	0.18	0.34	0.37	2.76
2) Use - supplies	Fuel	309.00	33.70	127.00	665.00	1,134.70
	Lubricant	3.92	0.64	2.21	11.30	18.07
	Ice	1,240.00	4.66	69.40	54.90	1,368.96
3) Use - Maintenance	Fishing vessel	9.20	1.15	2.21	2.64	15.20
	Engine	2.00	0.33	1.13	5.75	9.21
	Fishing gear	0.69	0.10	1.34	2.00	4.14
4) End of life	Fishing vessel	0.29	0.05	3.06	0.29	3.69
	Fishing gear	0.01	0.00	0.01	0.01	0.04
	Fish container	0.01	0.01	0.02	0.03	0.07
	Fuel container	0.00	0.00	0.00	0.00	0.00
	Lamps	0.00	0.00	0.01	0.00	0.01
Total		1,591.22	42.38	218.51	759.85	2,611.94

4. LF vessel

a. Characterisation (midpoint result)

Life stage	Fishing attributes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1) Production	Fishing vessel	3.11	2.04	0.45	678.26	0.00	0.15	8,803.27	2,709.50	2.19	187.98	0.53	0.03	95.35	1,311.67	17.08
	Fishing gear	110.78	2.56	0.35	1,019.60	0.00	0.81	11,884.42	2,478.21	8.76	1.91	2.35	0.09	730.12	28,223.31	1.13
	Fish container	0.01	0.01	0.00	26.62	0.00	0.00	136.70	29.69	0.01	0.01	0.00	0.00	3.55	59.12	0.01
	Fuel container	1.99	2.24	0.01	0.00	0.00	0.00	30.33	0.10	0.23	0.00	0.08	0.00	13.83	505.83	0.00
	Lamps	11.75	53.11	0.21	1,078.59	0.00	0.04	43,343.08	6,630.01	2.57	3.34	0.74	0.53	83.97	1,190.10	206.70
2) Use - supplies	Fuel	2,429.53	151.84	17.36	445,499.83	0.01	17.02	2,367,279.40	521,433.95	280.07	113.64	109.51	5.32	11,928.01	1,021,552.88	263.81
	Lubricant	10.42	8.82	0.89	20,786.52	0.00	3.70	103,845.34	24,125.63	12.55	8.04	4.68	0.28	541.66	42,429.87	40.28
	Ice	n/a														
3) Use - Maintenance	Fishing vessel	19.79	8.96	1.44	1,923.61	0.00	0.42	86,770.36	7,936.80	8.74	229.83	2.59	0.23	373.71	6,363.22	76.55
	Engine	2.57	2.18	0.22	5,132.67	0.00	0.91	25,641.81	5,957.18	3.10	1.98	1.15	0.07	133.75	10,476.91	9.95
	Fishing gear	9.56	1.95	0.16	1,580.74	0.00	0.31	12,423.92	785.08	3.86	2.06	0.94	0.16	380.02	16,163.13	0.65
4) End of life	Fishing vessel	0.12	0.53	0.04	273.16	0.00	0.09	320.62	510.12	1.46	0.00	0.27	0.03	245.23	432.99	-4.26
	Fishing gear	1.60	7.44	0.25	1,879.47	0.00	0.24	1,100.96	1,007.42	10.65	0.00	1.85	0.09	725.17	3,593.76	-2.10
	Fish container	0.03	0.17	0.02	72.37	0.00	0.00	2,064.82	549.23	0.71	0.00	0.13	0.03	14.61	137.23	-0.33
	Fuel container	0.00	0.00	0.00	0.35	0.00	0.00	2.18	2.43	0.00	0.00	0.00	0.00	0.06	1.12	0.00
	Lamps	0.00	0.00	0.00	1.24	0.00	0.00	36.44	26.65	0.01	0.00	0.00	0.01	1.93	4.23	0.00

Note: 1. Carcinogen (kg C_2H_3Cl eq); 2. Non-carcinogen (kg C_2H_3Cl eq); 3. Respiratory inorganic (kg $PM_{2.5}$ eq); 4. Ionizing radiations (Bq C-14 eq); 5. Ozone layer depletion (kg CFC-11 eq); 6. Respiratory organics (kg C_2H_4 eq); 7. Aquatic ecotoxicity (kg TEG water); 8. Teresstrial ecotoxicity (kg TEG soil); 9. Terrestrial acidification/nitrification (kg SO_2 eq); 10. Land occupation (m^2org.arable); 11. Aquatic acidification (kg SO_2 eq); 12. Aquatic eutropication (kg PO_4 P-lim); 13. Global warming (kg CO_2 eq); 14. Non-renewable energy (MJ primary); 15. Mineral extraction (MJ surplus)

b. **Damage assessment (endpoint result)**

Life stage		Human health	Ecosystem Quality	Climate change	Resources use	Total
		mPt	mPt	mPt	mPt	mPt
1) Production	Fishing vessel	46.60	16.70	9.63	8.74	81.67
	Fishing gear	289.90	3.99	194.01	482.46	970.36
	Fish container	0.07	0.02	0.36	0.39	0.84
	Fuel container	2.92	0.02	1.40	3.33	7.67
	Lamps	46.80	4.45	8.48	9.19	68.92
2) Use - supplies	Fuel	2,757.00	339.70	1,204.00	6,730.00	11,030.70
	Lubricant	97.10	15.90	54.70	279.00	446.70
	Ice					0.00
3) Use - Maintenance	Fishing vessel	153.00	23.87	37.80	42.00	256.67
	Engine	24.00	3.93	13.50	69.00	110.43
	Fishing gear	49.60	0.68	33.19	82.54	166.01
4) End of life	Fishing vessel	3.82	0.41	24.82	2.82	31.87
	Fishing gear	28.93	1.63	74.32	24.75	129.62
	Fish container	1.78	0.38	1.48	0.90	4.54
	Fuel container	0.00	0.00	0.01	0.01	0.02
	Lamps	0.03	0.02	0.19	0.03	0.27
Total		3,501.56	411.69	1,657.88	7,735.16	13,306.01

These result is presented per year, impacts per kg catch and £ revenue are calculated using the following inputs

Fishing vessel	Annual Catch (kg)	Annual Value (£)
PD vessel	58,060	31,941
TN vessel	3,194	6,488
HL vessel	4,182	6,257
LF vessel	90,456	34,977

Appendix K. Inventory analysis for LCC

1. PD vessel

Cost components	Input (£)	Lifetime/Frequency
1) Investment		
Fishing vessel	1,510	20 years
Engine	997	3 years
Fishing gear	755	10 years
Fish container	29	5 years
Fuel container	11	5 years
2) Operation		
Petrol	1,303	1 year
Ice	182	
Personnel	2,501	
Selling	-	
3) Maintenance		
Fishing vessel		
Hull	227	Every 2 years
Repainting	56	Every 3 months
Engine	9	Every 3 months
Fishing gear		
Net	725	Every year
Float	16	Every 5 years
Rope	88	Every 5 years
4) End of life		
Fishing vessel	604	
Engine	30	

2. TN vessel

Cost components	Input (£)	Lifetime/Frequency
1) Investment		
Fishing vessel	1,510	20 years
Engine	997	3 years
Fishing gear	755	10 years
Fish container	29	5 years
Fuel container	11	5 years
2) Operation		
Petrol	1,303	1 year
Ice	182	
Personnel	2,501	
Selling	-	
3) Maintenance		
Fishing vessel		
Hull	227	Every 2 years
Repainting	56	Every 3 months
Engine	9	Every 3 months
Fishing gear		
Net	725	Every year
Float	16	Every 5 years
Rope	88	Every 5 years
4) End of life		
Fishing vessel	604	
Engine	30	

3. HL vessel

Cost components	Input (£)	Lifetime/Frequency
1) Investment		
Fishing vessel	1,208	20 years
Engine	586	5 years
Fishing gear	72	5 years
Fish container	2	1 month
Fuel container	2	5 years
Lamps	16	4 years
2) Operation		
Petrol	892	1 year
Lubricant	43	
Ice	178	
Bait	214	
Personnel	2,963	
Selling	626	
3) Maintenance		
Fishing vessel		
Hull	46	Every 3 years
Repainting	12	Every 3 years
Engine	22	Every week
Fishing gear	50	Every week
4) End of life		
Fishing vessel	302	
Engine	27	

4. LF vessel

Cost components	Input (£)	Lifetime/ Frequency
1) Investment		
Fishing vessel	3,624	20 years
Engine	1,510	10 years
Fishing gear		
Bamboo	906	10 years
Net	91	3 years
Generator	151	5 years
Plastic drums	190	3 years
Fish container	12	1 years
Fuel container	2	5 years
Lamps	40	4 years
2) Operation		
Diesel	1605	1 year
Petrol/Platform	684	
Lubricant/Platform	104	
Personnel	9,430	Every year
Selling	3,498	Every year
3) Maintenance		
Fishing vessel		
Hull	379	Every 2 years
Repainting	83	Every 4 months
Engine	22	Every month
Fishing gear	227	Every 2.5 year
4) End of life		
Fishing vessel	1,812	
Engine	151	
Fishing gear	211	

Appendix L. LCC calculation

1. PD vessel

Year	Inflation rate	Present value									
		Investment cost					Other cost				Residual
		Fishing vessel	Engine	Fishing gear	Fish container	Fuel container	Maintenance	Supplies	Personnel	Marketing	
1	2	3	4	5	6	7	8	9	10	11	12
0	1.00	2,718	2,416	906	53	8	0	0	0	0	0
1	1.05	0	0	0	0	0	1,177	10,485	12,457	3,194	0
2	1.09	0	0	0	0	0	1,505	10,485	12,208	3,130	0
3	1.14	0	0	0	0	0	1,177	10,485	11,964	3,068	0
4	1.20	0	0	0	0	0	1,505	10,485	11,725	3,006	0
5	1.25	0	0	0	0	0	1,297	10,485	11,490	2,946	0
6	1.31	0	0	0	53	8	1,505	10,485	11,260	2,887	0
7	1.37	0	0	0	0	0	1,177	10,485	11,035	2,830	60
8	1.43	0	2,416	0	0	0	1,505	10,485	10,814	2,773	0
9	1.50	0	0	0	0	0	1,177	10,485	10,598	2,717	0
10	1.57	0	0	0	0	0	1,624	10,485	10,386	2,663	121
11	1.64	0	0	906	53	8	1,177	10,485	10,178	2,610	0
12	1.71	0	0	0	0	0	1,505	10,485	9,975	2,558	0
13	1.79	0	0	0	0	0	1,177	10,485	9,775	2,506	0
14	1.87	0	0	0	0	0	1,505	10,485	9,580	2,456	60
15	1.96	0	2,416	0	0	0	1,297	10,485	9,388	2,407	0
16	2.05	0	0	0	53	8	1,505	10,485	9,200	2,359	0
17	2.14	0	0	0	0	0	1,177	10,485	9,016	2,312	0
18	2.24	0	0	0	0	0	1,505	10,485	8,836	2,266	0
19	2.35	0	0	0	0	0	1,177	10,485	8,659	2,220	0
20	2.45	0	0	0	0	0	1,177	10,485	8,486	2,176	1,726
Total		2,718	7,249	1,812	211	33	26,850	209,690	207,033	53,085	1,967

Future value						LCC components (Discounted value)						
Investment cost	Other costs				Residual							
	Maintenance	Supplies	Personnel	Selling		Investment	Maintenance	Supplies	Personnel	Selling	Residual	Total
13	14	15	16	17	18	19	20	21	22	23	24	25
6,101	0	0	0	0	0	6,101	0	0	0	0	0	6,101
0	1,231	10,966	13,029	3,341	0	0	1,150	10,241	12,167	3,120	0	26,678
0	1,646	11,469	13,354	3,424	0	0	1,435	10,003	11,647	2,986	0	26,071
0	1,347	11,996	13,688	3,510	0	0	1,097	9,770	11,148	2,859	0	24,874
0	1,800	12,546	14,030	3,597	0	0	1,369	9,543	10,671	2,736	0	24,320
0	1,623	13,122	14,380	3,687	0	0	1,153	9,321	10,215	2,619	0	23,308
80	1,969	13,724	14,740	3,779	0	53	1,306	9,104	9,778	2,507	0	22,748
0	1,612	14,354	15,108	3,874	83	0	998	8,892	9,359	2,400	51	21,599
3,460	2,154	15,013	15,485	3,971	0	2,002	1,246	8,686	8,959	2,297	0	23,190
0	1,763	15,702	15,872	4,070	0	0	953	8,484	8,576	2,199	0	20,211
0	2,545	16,423	16,269	4,171	189	0	1,284	8,286	8,209	2,105	95	19,788
1,584	1,929	17,177	16,675	4,276	0	747	909	8,094	7,857	2,015	0	19,621
0	2,578	17,965	17,092	4,383	0	0	1,134	7,906	7,521	1,929	0	18,490
0	2,110	18,790	17,519	4,492	0	0	867	7,722	7,199	1,846	0	17,634
0	2,820	19,652	17,956	4,604	113	0	1,082	7,542	6,891	1,767	43	17,239
4,737	2,543	20,554	18,405	4,719	0	1,698	911	7,367	6,596	1,691	0	18,264
125	3,085	21,498	18,865	4,837	0	42	1,033	7,195	6,314	1,619	0	16,203
0	2,524	22,484	19,336	4,958	0	0	789	7,028	6,044	1,550	0	15,411
0	3,375	23,516	19,819	5,082	0	0	985	6,865	5,785	1,483	0	15,119
0	2,762	24,596	20,314	5,209	0	0	753	6,705	5,538	1,420	0	14,416
0	2,888	25,725	20,822	5,339	4,235	0	735	6,549	5,301	1,359	1,078	12,867
16,087	**44,304**	**347,272**	**332,759**	**85,323**	**4,620**	**10,642**	**21,191**	**165,301**	**165,778**	**42,507**	**1,268**	**404,151**

The same procedure was applied for the remaining vessels, the following table shows the final result

2. TN vessel

Year	LCC components (Discounted value)					Total
	Investment	Maintenance cost	Supplies cost	Personnel cost	Residual	
0	3,302	0	0	0	0	3,302
1	0	964	1,451	2,443	0	4,859
2	28	1,158	1,417	2,339	0	4,942
3	27	920	1,384	2,239	28	4,542
4	439	1,105	1,352	2,143	0	5,038
5	26	970	1,321	2,051	0	4,368
6	35	1,054	1,290	1,963	26	4,316
7	409	837	1,260	1,879	0	4,386
8	24	1,006	1,231	1,799	0	4,059
9	23	799	1,202	1,722	24	3,722
10	381	1,042	1,174	1,648	24	4,221
11	1,033	762	1,147	1,578	0	4,520
12	22	915	1,120	1,510	23	3,545
13	355	727	1,094	1,446	0	3,622
14	21	873	1,069	1,384	0	3,346
15	20	767	1,044	1,325	21	3,134
16	338	678	1,019	1,268	0	3,303
17	19	814	996	1,214	0	3,043
18	19	647	973	1,162	20	2,780
19	308	776	950	1,112	0	3,147
20	18	758	928	1,064	503	2,266
Total	**6,847**	**17,573**	**23,419**	**33,288**	**670**	**80,457**

3. HL vessel

Year	LCC components (Discounted value)						Total
	Investment	Maintenance cost	Supplies cost	Personnel cost	Marketing fee	Residual	
0	1,913	0	0	0	0	0	1,913
1	0	70	1,296	2,894	611	0	4,872
2	97	69	1,266	2,771	585	0	4,787
3	95	121	1,237	2,652	560	0	4,664
4	92	66	1,208	2,539	536	0	4,440
5	104	64	1,180	2,430	513	24	4,267
6	598	113	1,152	2,326	491	0	4,680
7	86	61	1,125	2,226	470	0	3,969
8	84	60	1,099	2,131	450	0	3,824
9	95	105	1,074	2,040	431	0	3,744
10	80	57	1,049	1,953	412	21	3,529
11	532	56	1,024	1,869	395	0	3,876
12	77	98	1,001	1,789	378	0	3,342
13	86	53	977	1,713	362	0	3,191
14	73	52	955	1,639	346	0	3,065
15	71	91	932	1,569	331	19	2,976
16	473	49	911	1,502	317	0	3,252
17	79	49	890	1,438	304	0	2,758
18	66	85	869	1,376	291	0	2,687
19	65	46	849	1,317	278	0	2,555
20	63	45	829	1,261	266	206	2,259
Total	**4,830**	**1,406**	**20,922**	**39,435**	**8,326**	**270**	**74,649**

4. LF vessel

Year	LCC components (Discounted value)										Total
	Ferry				10 Platforms				Marketing fee	Personnel cost	
	Investment	Supplies cost	Maintenance cost	Residual	Investment	Supplies cost	Maintenance cost	Residual			
0	5,134	0	0	0	13,793	0	0	0	0	0	18,928
1	0	1,568	499	0	118	7,697	0	0	3,416	9,211	22,510
2	0	1,531	849	0	115	7,518	2,161	0	3,270	8,817	24,262
3	0	1,496	476	0	2,730	7,344	0	169	3,130	8,440	23,447
4	0	1,461	810	0	473	7,173	2,062	0	2,996	8,079	23,053
5	0	1,427	454	0	1,463	7,006	0	107	2,868	7,733	20,844
6	0	1,394	773	0	2,544	6,843	1,967	157	2,745	7,402	23,510
7	0	1,361	433	0	102	6,684	0	0	2,628	7,085	18,294
8	0	1,330	737	0	430	6,529	1,877	0	2,515	6,782	20,200
9	0	1,299	414	0	98	6,377	0	0	2,408	6,492	17,087
10	0	1,269	703	119	10,682	6,228	1,790	2,387	2,305	6,214	26,685
11	1,166	1,239	394	0	93	6,084	0	0	2,206	5,948	17,131
12	0	1,210	671	0	392	5,942	1,708	0	2,112	5,694	17,729
13	0	1,182	376	0	2,158	5,804	0	133	2,021	5,450	16,858
14	0	1,155	640	0	87	5,669	1,629	0	1,935	5,217	16,332
15	0	1,128	359	0	1,157	5,537	0	85	1,852	4,994	14,942
16	0	1,102	611	0	2,284	5,408	1,555	124	1,773	4,780	17,388
17	0	1,076	343	0	81	5,283	0	0	1,697	4,575	13,055
18	0	1,051	583	0	79	5,160	1,483	0	1,624	4,380	14,360
19	0	1,027	327	0	77	5,040	0	0	1,555	4,192	12,218
20	0	1,003	556	1,226	75	4,923	0	1,887	1,488	4,013	8,945
Total	**6,300**	**25,308**	**11,007**	**1,346**	**39,032**	**124,248**	**16,232**	**5,050**	**46,546**	**125,498**	**387,776**

Appendix M. Financial analysis

1. PD vessel

Financial analysis for the common scenario

Cost component	Year																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Investment																					
Fishing vessel	2,718	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	2,416	0	0	0	0	0	0	0	3,460	0	0	0	0	0	0	4,737	0	0	0	0	0
Fishing gear	906	0	0	0	0	0	0	0	0	0	0	1,484	0	0	0	0	0	0	0	0	0
Fish container	53	0	0	0	0	0	69	0	0	0	0	87	0	0	0	0	108	0	0	0	0
Fuel container	8	0	0	0	0	0	11	0	0	0	0	13	0	0	0	0	17	0	0	0	0
Total investment	**6,101**	**0**	**0**	**0**	**0**	**0**	**80**	**0**	**3,460**	**0**	**0**	**1,584**	**0**	**0**	**0**	**4,737**	**125**	**0**	**0**	**0**	**0**
Cash outflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance cost	0	1,231	1,646	1,347	1,800	1,623	1,969	1,612	2,154	1,763	2,545	1,929	2,578	2,110	2,820	2,543	3,085	2,524	3,375	2,762	2,888
Supplies cost	0	10,966	11,469	11,996	12,546	13,122	13,724	14,354	15,013	15,702	16,423	17,177	17,965	18,790	19,652	20,554	21,498	22,484	23,516	24,596	25,725
Marketing cost	0	3,341	3,424	3,510	3,597	3,687	3,779	3,874	3,971	4,070	4,171	4,276	4,383	4,492	4,604	4,719	4,837	4,958	5,082	5,209	5,339
Personnel cost	0	13,029	13,354	13,688	14,030	14,380	14,740	15,108	15,485	15,872	16,269	16,675	17,092	17,519	17,956	18,405	18,865	19,336	19,819	20,314	20,822
Total cash outflow	**0**	**28,567**	**29,894**	**30,540**	**31,974**	**32,813**	**34,213**	**34,948**	**36,624**	**37,407**	**39,408**	**40,056**	**42,017**	**42,910**	**45,033**	**46,221**	**48,285**	**49,303**	**51,792**	**52,880**	**54,774**
Cash inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Income from fishing	0	33,408	34,242	35,098	35,974	36,873	37,794	38,738	39,706	40,698	41,715	42,757	43,825	44,920	46,042	47,192	48,371	49,580	50,818	52,088	53,389
Residual	0	0	0	0	0	0	0	83	0	0	189	0	0	0	113	0	0	0	0	0	4,235
Total cash inflow	**0**	**33,408**	**34,242**	**35,098**	**35,974**	**36,873**	**37,794**	**38,821**	**39,706**	**40,698**	**41,904**	**42,757**	**43,825**	**44,920**	**46,155**	**47,192**	**48,371**	**49,580**	**50,818**	**52,088**	**57,624**
Net cash inflow	-6,101	4,841	4,349	4,557	4,000	4,060	3,501	3,873	-377	3,291	2,496	1,116	1,808	2,010	1,122	-3,766	-38	277	-974	-793	2,850
Present value	-6,101	4,521	3,793	3,712	3,043	2,884	2,323	2,400	-218	1,778	1,260	526	795	826	431	-1,350	-13	87	-284	-216	726
Net invested cash	-6,101	-1,261	3,088	7,645	11,646	15,706	19,207	23,081	22,703	25,994	28,491	29,607	31,415	33,425	34,547	30,781	30,743	31,020	30,046	29,253	32,103

The same procedure was applied for optimistic and pessimistic scenarios and the result is presented below

Financial indicators	Common	Optimistic	Pessimistic
NPV (£)	20,923	47,822	-5,982
PP (years)	1.3	0.90	3
IRR	72.85%	96%	n/a

2. TN vessel

Financial analysis for the common scenario

Cost component	Year																				
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Investment																					
Fishing vessel	1,510	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	997	0	0	0	542	0	0	620	0	0	710	891	0	812	0	0	929	0	0	1,063	0
Fishing gear	755	0	0	0	0	0	0	0	0	0	0	1,237	0	0	0	0	0	0	0	0	0
Fish container	29	0	32	33	35	36	38	40	42	43	45	48	50	52	54	57	59	62	65	68	71
Fuel container	11	0	0	0	0	0	14	0	0	0	0	18	0	0	0	0	22	0	0	0	0
Total investment	**3,302**	**0**	**32**	**33**	**577**	**36**	**52**	**660**	**42**	**43**	**755**	**2,193**	**50**	**864**	**54**	**57**	**1,011**	**62**	**65**	**1,131**	**71**
Cash outflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance cost	0	1,033	1,328	1,130	1,453	1,366	1,589	1,352	1,738	1,479	2,064	1,618	2,080	1,770	2,275	2,139	2,025	2,603	2,215	2,848	2,978
Supplies cost	0	1,554	1,625	1,699	1,777	1,859	1,944	2,034	2,127	2,225	2,327	2,434	2,545	2,662	2,784	2,912	3,046	3,186	3,332	3,485	3,645
Personnel cost	0	2,616	2,682	2,749	2,817	2,888	2,960	3,034	3,109	3,187	3,267	3,348	3,432	3,518	3,606	3,696	3,788	3,883	3,980	4,079	4,181
Total cash outflow	**0**	**5,203**	**5,634**	**5,578**	**6,047**	**6,113**	**6,493**	**6,419**	**6,975**	**6,891**	**7,658**	**7,400**	**8,057**	**7,949**	**8,665**	**8,747**	**8,858**	**9,672**	**9,526**	**10,412**	**10,804**
Cash inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Income from fishing	0	6,786	6,956	7,129	7,307	7,490	7,677	7,869	8,065	8,267	8,473	8,685	8,902	9,125	9,352	9,586	9,826	10,071	10,323	10,581	10,845
Residual	0	0	0	35	0	0	40	0	0	45	47	0	52	0	0	59	0	0	68	0	1,976
Total cash inflow	**0**	**6,786**	**6,956**	**7,164**	**7,307**	**7,490**	**7,717**	**7,869**	**8,065**	**8,312**	**8,521**	**8,685**	**8,954**	**9,125**	**9,352**	**9,645**	**9,826**	**10,071**	**10,390**	**10,581**	**12,821**
Net cash inflow	-3,302	1,583	1,289	1,553	683	1,341	1,171	790	1,049	1,378	108	-907	847	311	633	841	-43	337	799	-962	1,946
Present value	-3,302	1,479	1,125	1,265	520	953	777	489	607	745	54	-428	373	128	243	302	-15	105	233	-262	513
Net invested cash	-3,302	-1,718	-429	1,124	1,807	3,149	4,320	5,110	6,159	7,537	7,645	6,738	7,584	7,896	8,528	9,370	9,326	9,664	10,463	9,501	11,518

The same procedure was applied for optimistic and pessimistic scenarios and the result is presented below

Financial indicators	Common	Optimistic	Pessimistic
NPV (£)	5,904	12,282	-472
PP (years)	2.3	1.7	3
IRR	37.94%	56%	n/a

3. HL vessel

Cost component	Year																				
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Investement cost																					
Fishing vessel	1,208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	423	0	0	0	0	0	553	0	0	0	0	693	0	0	0	0	867	0	0	0	0
Generator	163	0	0	0	0	0	213	0	0	0	0	267	0	0	0	0	334	0	0	0	0
Fishing gear	72	0	79	83	87	91	95	99	104	109	114	119	124	130	136	142	149	155	163	170	178
Fish container	2	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	3	0	0	0	0
Fuel container	29	0	32	33	35	36	38	40	42	43	45	48	50	52	54	57	59	62	65	68	71
Lamps	16	0	0	0	0	20	0	0	0	24	0	0	0	29	0	0	0	34	0	0	0
Total investment	**1,913**	**0**	**111**	**116**	**121**	**147**	**902**	**139**	**145**	**176**	**159**	**1,129**	**174**	**210**	**190**	**199**	**1,413**	**252**	**228**	**238**	**249**
Cash outflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vessel maintenance cost	0	23	24	91	26	27	104	30	31	119	34	36	136	39	41	155	45	47	177	51	53
Mear maintenance cost	0	53	55	57	60	63	66	69	72	75	79	82	86	90	94	99	103	108	113	118	123
Supplies cost	0	1,388	1,452	1,518	1,588	1,661	1,737	1,817	1,900	1,987	2,079	2,174	2,274	2,378	2,487	2,601	2,721	2,846	2,976	3,113	3,256
Marketing cost	0	654	671	688	705	722	740	759	778	797	817	838	858	880	902	924	948	971	995	1,020	1,046
Personnnel cost	0	3,099	3,177	3,256	3,337	3,421	3,506	3,594	3,684	3,776	3,870	3,967	4,066	4,167	4,271	4,378	4,488	4,600	4,715	4,832	4,953
Total cash outflow	**0**	**5,217**	**5,378**	**5,610**	**5,716**	**5,894**	**6,153**	**6,268**	**6,465**	**6,754**	**6,879**	**7,096**	**7,420**	**7,554**	**7,796**	**8,158**	**8,304**	**8,571**	**8,977**	**9,135**	**9,431**
Cash inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Income from fishing	0	6,544	6,708	6,875	7,047	7,223	7,403	7,588	7,778	7,972	8,171	8,375	8,585	8,799	9,019	9,244	9,475	9,712	9,955	10,203	10,458
Residual	0	0	0	0	0	34	0	0	0	0	43	0	0	0	0	53	0	0	0	0	808
Total cash inflow	**0**	**6,544**	**6,708**	**6,875**	**7,047**	**7,257**	**7,403**	**7,588**	**7,778**	**7,972**	**8,214**	**8,375**	**8,585**	**8,799**	**9,019**	**9,298**	**9,475**	**9,712**	**9,955**	**10,203**	**11,266**
Net cash inflow	-1,913	1,327	1,219	1,149	1,209	1,216	349	1,181	1,168	1,042	1,176	151	991	1,034	1,033	941	-241	889	750	831	1,585
Present value	-1,913	1,239	1,063	936	920	864	231	732	676	563	594	71	436	425	396	337	-81	278	219	226	404
Net invested cash	-1,913	-586	633	1,782	2,991	4,207	4,556	5,737	6,905	7,947	9,123	9,274	10,265	11,299	12,332	13,273	13,032	13,921	14,672	15,502	17,088

The same procedure was applied for optimistic and pessimistic scenarios and the result is presented below

Financial indicators	Common	Optimistic	Pessimistic
NPV (£)	8,616	12,830	4,402
PP (years)	1.4	1.10	2.00
IRR	63.43%	82%	43%

4. LF vessel

Cost component	Year																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Investment																					
Fishing vessel	3,624	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	1,510	0	0	0	0	0	0	0	0	0	0	2,474	0	0	0	0	0	0	0	0	0
Fishing gear																					
Bamboo	9,061	0	0	0	0	0	0	0	0	0	14,193	0	0	0	0	0	0	0	0	0	0
Plastic drums	1,903	0	0	2,177	0	0	2,491	0	0	0	2,980	0	0	3,410	0	0	3,901	0	0	0	0
Net	906	0	0	1,037	0	0	1,186	0	0	0	1,419	0	0	1,624	0	0	1,858	0	0	0	0
Generator	1,510	0	0	0	0	1,890	0	0	0	0	2,365	0	0	0	0	2,960	0	0	0	0	0
Lamps	399	0	0	0	477	0	0	0	571	0	0	0	683	0	0	0	817	0	0	0	0
Fish container	0	126	132	138	145	151	158	165	173	181	189	198	207	217	226	237	248	259	271	283	296
Fuel container	15	0	0	0	0	19	0	0	0	0	24	0	0	0	0	30	0	0	0	0	0
Total investment	**18,928**	**126**	**132**	**3,352**	**622**	**2,060**	**3,835**	**165**	**744**	**181**	**21,171**	**2,672**	**890**	**5,250**	**226**	**3,227**	**6,824**	**259**	**271**	**283**	**296**
Cash outflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance cost	0	534	3,451	585	3,775	640	4,130	700	4,518	765	4,942	837	5,406	916	5,914	1,002	6,469	1,096	7,076	1,199	2,183
Supplies cost	0	9,921	10,377	10,853	11,351	11,872	12,417	12,987	13,583	14,206	14,859	15,541	16,254	17,000	17,780	18,596	19,450	20,343	21,276	22,253	23,274
Marketing cost	0	3,658	3,750	3,843	3,939	4,038	4,139	4,242	4,348	4,457	4,568	4,682	4,799	4,919	5,042	5,168	5,297	5,429	5,565	5,704	5,846
Personnel cost	0	9,863	10,110	10,362	10,621	10,886	11,158	11,437	11,723	12,016	12,316	12,624	12,939	13,262	13,593	13,933	14,281	14,638	15,004	15,378	15,763
Total cash outflow	**0**	**23,977**	**27,687**	**25,643**	**29,687**	**27,436**	**31,844**	**29,366**	**34,171**	**31,444**	**36,684**	**33,683**	**39,398**	**36,097**	**42,329**	**38,699**	**45,497**	**41,506**	**48,921**	**44,534**	**47,066**
Cash inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Income from platform	0	36,582	37,496	38,433	39,393	40,377	41,385	42,419	43,479	44,565	45,679	46,820	47,989	49,188	50,417	51,677	52,968	54,291	55,647	57,037	58,462
Other incomes	0	0	0	207	0	151	237	0	0	0	4,967	0	0	325	0	237	372	0	0	0	12,227
Total cash inflow	**0**	**36,582**	**37,496**	**38,640**	**39,393**	**40,528**	**41,623**	**42,419**	**43,479**	**44,565**	**50,646**	**46,820**	**47,989**	**49,513**	**50,417**	**51,913**	**53,339**	**54,291**	**55,647**	**57,037**	**70,689**
Net cash inflow	-18,928	12,478	9,677	9,645	9,084	11,032	5,944	12,888	8,564	12,940	-7,209	10,464	7,702	8,166	7,862	9,988	1,018	12,526	6,455	12,220	23,327
Present value	-18,928	11,653	8,439	7,856	6,910	7,836	3,943	7,984	4,954	6,991	-3,637	4,931	3,389	3,356	3,017	3,580	341	3,915	1,884	3,331	6,014
Net invested cash	-18,928	-6,449	3,227	12,872	21,957	32,989	38,933	51,821	60,385	73,325	66,116	76,581	84,282	92,448	100,310	110,297	111,315	123,841	130,296	142,516	166,139

The same procedure was applied for optimistic and pessimistic scenarios and the result is presented below

Financial indicators	Common	Optimistic	Pessimistic
NPV (£)	77,759	149,951	13,533
PP (years)	1.7	1.10	3.6
IRR	55.62%	89%	20%

Appendix N. Sensitivity analysis

Note: 0 indicates the input variables used for developing the profit model, and the values are presented in Appendix G

1. PD vessel

a. Number of trips/month

Change in the number of the trips/month	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-10	-3,473	8,946	-15,894	0%	28%	0%	453	508	398	2,919	3,852	1,986
-8	1,404	16,722	-13,912	24%	43%	0%	554	622	486	3,497	4,648	2,346
-6	6,283	24,496	-11,930	39%	57%	0%	655	736	574	4,074	5,443	2,705
-4	11,164	32,271	-9,948	51%	70%	0%	756	849	663	4,651	6,237	3,065
-2	16,041	40,046	-7,964	62%	83%	0%	857	963	751	5,228	7,032	3,424
0	20,923	47,822	-5,982	73%	96%	0%	958	1,077	839	5,806	7,828	3,784
+2	25,799	55,599	-3,998	83%	109%	7%	1,059	1,191	927	6,383	8,622	4,144
+4	30,678	63,373	-2,015	94%	122%	2%	1,160	1,305	1,015	6,960	9,417	4,503

b. Fuel/trip

Change in fuel/trip (litres)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-15	44,432	71,335	17,530	101.38%	122%	53%	958	1,077	839	7,297	9,318	5,275
-10	36,595	63,497	9,694	92.10%	113%	42%	958	1,077	839	6,800	8,821	4,778
-5	28,756	55,659	1,856	82.62%	105%	31%	958	1,077	839	6,303	8,324	4,281
0	20,923	47,822	-5,982	73%	96%	0%	958	1,077	839	5,806	7,828	3,784
+5	13,082	39,985	-13,819	66%	91%	0%	958	1,077	839	5,309	7,331	3,287
+10	5,247	32,146	-21,656	63%	88%	0%	958	1,077	839	4,811	6,833	2,789
+15	-2,592	24,308	-29,495	11%	70%	0%	958	1,077	839	4,314	6,336	2,292

c. Fuel price

Change in fuel price (Rp)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
0	20,923	47,822	-5,982	73%	96%	0%	958	1,077	839	5,806	7,828	3,784
+250	15,661	42,564	-11,238	66%	91%	0%	958	1,077	839	4,911	6,933	2,889
+500	10,406	37,309	-16,496	59%	85%	0%	958	1,077	839	4,464	6,486	2,442
+750	5,150	32,050	-21,753	1%	79%	0%	958	1,077	839	4,017	6,039	1,995
+1000	-110	26,793	-27,009	7%	73%	0%	958	1,077	839	4,472	6,493	2,450

d. Catch/trip

Change in catch/trip (kg)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-25	4,205	28,987	-20,580	1%	72%	0%	884	994	774	4,550	6,412	2,688
-20	7,547	32,755	-17,660	52%	77%	0%	899	1,010	788	4,801	6,695	2,907
-15	10,890	36,521	-14,740	58%	82%	0%	914	1,027	801	5,052	6,978	3,126
-10	14,233	40,290	-11,820	63%	87%	0%	929	1,044	814	5,303	7,261	3,345
-5	17,579	44,055	-8,902	68%	92%	0%	943	1,060	826	5,554	7,544	3,564
0	20,923	47,822	-5,982	73%	96%	0%	958	1,077	839	5,806	7,828	3,784

e. Fish price

Change in fish price (Rp)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-1,000	-2,882	21,117	-26,883	13%	62%	0%	853	959	747	4,805	6,608	3,002
-750	3,072	27,793	-21,656	2%	71%	0%	879	988	770	5,139	6,997	3,281
-500	9,019	34,470	-16,432	55%	79%	0%	906	1,018	794	5,472	7,384	3,560
0	20,923	47,822	-5,982	73%	96%	0%	958	1,077	839	5,806	7,828	3,784

f. Owner’s share

Change in owner's share (%)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-7%	-759	23,454	-24,971	8%	65%	0%	1,150	1,293	1,293	4,177	5,996	2,358
-6%	2,493	27,108	-22,123	3%	70%	0%	1,121	1,260	982	4,421	6,271	2,571
-5%	5,745	30,765	-19,273	49%	75%	0%	1,092	1,228	956	4,665	5,845	3,485
-4%	8,995	34,419	-16,426	55%	79%	0%	1,064	1,196	932	4,910	6,820	3,000
-3%	12,246	38,075	-13,577	60%	84%	0%	1,035	1,163	907	5,154	7,095	3,213
-2%	15,502	41,731	-10,730	65%	89%	0%	1,006	1,131	881	5,398	7,369	3,427
-1%	18,752	45,384	-7,881	70%	93%	0%	977	1,098	856	5,643	7,644	3,642
0%	20,923	47,822	-5,982	73%	96%	0%	958	1,077	839	5,806	7,828	3,784

g. Number of fishers

Change in the number of fishers	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
7	20,923	47,822	-5,982	73%	96%	0%	1,369	1,539	1,199	5,806	7,827	3,784
8	20,923	47,822	-5,982	73%	96%	0%	1,198	1,346	1,049	5,806	7,827	3,784
9	20,923	47,822	-5,982	73%	96%	0%	1,065	1,197	933	5,806	7,827	3,784
10	20,923	47,822	-5,982	73%	96%	0%	958	1,077	839	5,806	7,828	3,784
11	20,923	47,822	-5,981	73%	96%	0%	806	1,019	794	5,807	7,829	3,785
12	20,923	47,822	-5,980	73%	96%	0%	670	848	661	5,808	7,830	3,786
13	20,923	47,822	-5,979	73%	96%	0%	533	677	527	5,809	7,831	3,787

2. TN vessel

a. Number of trips/month

Change in the number of the trips/month	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-4	70	5,164	-5,026	8%	34%	0%	670	774	566	2,009	2,320	1,698
-2	2,987	8,721	-2,751	27%	46%	0%	752	869	635	2,255	2,606	1,904
0	5,904	12,282	-472	38%	56%	0%	834	964	704	2,501	2,891	2,111
+2	8,821	15,841	1,802	48%	67%	24%	916	1,059	773	2,748	3,177	2,319
+4	11,739	19,400	4,075	56%	77%	33%	998	1,154	842	2,994	3,463	2,525

b. Fuel/trip

Change in fuel/trip (litres)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-5	9,320	15,399	3,241	46%	63%	27%	896	1,026	766	2,689	3,079	2,299
-4	8,636	14,776	2,499	45%	62%	24%	884	1,014	754	2,651	3,041	2,261
-3	7,953	14,153	1,755	43%	60%	21%	871	1,001	741	2,614	3,004	2,224
-2	7,268	13,526	1,012	41%	59%	18%	859	989	729	2,576	2,966	2,186
-1	6,587	12,905	267	40%	58%	12%	846	976	716	2,539	2,929	2,149
0	5,904	12,282	-472	38%	56%	0%	834	964	704	2,501	2,891	2,111
+1	5,223	11,657	-1,215	36%	55%	0%	821	951	691	2,464	2,854	2,074
+2	4,538	11,034	-1,961	34%	54%	0%	809	939	679	2,426	2,816	2,036
+3	3,854	10,413	-2,705	32%	52%	0%	796	926	666	2,389	2,779	1,999
+5	2,486	9,165	-4,189	28%	50%	0%	771	901	641	2,314	2,704	1,924
+9	-245	6,673	-7,161	0%	44%	0%	721	851	591	2,164	2,554	1,774

c. Fuel price

Change in fuel price (Rp)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
0	5,904	12,282	-472	38%	56%	0%	834	964	704	2,501	2,891	2,111
+1,000	3,597	10,179	-2983	31%	52%	0	792	922	662	2,375	2,765	1,985
+2,000	1,291	8,074	-5492	23%	47%	0%	749	879	619	2,248	2,638	1,858
+3,000	-1,014	5,970	-8000	0%	42%	0%	707	837	577	2,122	2,512	1,732

d. Catch/trip

Change in catch/trip (kg)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-3	-2,499	2,886	-7,882	0%	27%	0%	623	728	518	1,870	2,185	1,555
-2	304	6,020	-5,415	13%	38%	0%	694	807	581	2,081	2,421	1,741
-1	3,103	9,151	-2,944	28%	48%	0%	764	886	642	2,291	2,656	1,926
0	5,904	12,282	-472	38%	56%	0%	834	964	704	2,501	2,891	2,111

e. Fish price

Change in fish price (Rp)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-5,000	-516	5,087	-6,117	0%	35%	0%	673	784	562	2,019	2,351	1,687
-4,000	768	6,527	-4,989	17%	40%	0%	705	819	591	2,116	2,459	1,773
-3,000	2,053	7,965	-3,859	24%	44%	0%	737	855	619	2,212	2,567	1,857
-2,000	3,334	9,403	-2,730	29%	48%	0%	770	892	648	2,309	2,676	1,942
-1,000	4,622	10,844	-1,604	34%	52%	0%	802	928	676	2,405	2,783	2,027
0	5,904	12,282	-472	38%	56%	0%	834	964	704	2,501	2,891	2,111

f. Owner’s share

Change in owner's share (%)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-9%	-87	5569	-5744	0%	37%	0%	984	1,137	831	2,051	2,371	1,731
-8%	578	6315	-5161	15%	39%	0%	967	1,118	816	2,101	2,429	1,773
-7%	1,245	7,062	-4,574	20%	42%	0%	951	1,099	803	2,151	2,486	1,816
-6%	1,910	7,807	-3,987	23%	44%	0%	934	1,080	788	2,201	2,544	1,858
-5%	2,575	8553	-3402	26%	46%	0%	917	1,060	774	2,251	2,602	1,900
-4%	3,240	9298	-2819	29%	48%	0%	901	1,041	761	2,301	2,660	1,942
-3%	3,907	10,045	-2,230	31%	50%	0%	884	1,022	746	2,351	2,718	1,984
-2%	4,573	10,789	-1,645	34%	52%	0%	867	1,002	732	2,401	2,775	2,027
-1%	5,239	11,536	-1,061	36%	54%	0%	850	983	717	2,451	2,833	2,069
0%	5,904	12,282	-472	38%	56%	0%	834	964	704	2,501	2,891	2,111

g. Number of Fishers

Number of fishers (Person)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
2	5,904	12,282	-472	37.94%	56%	0%	1,251	1,446	1,056	2,501	2,891	2,111
3	5,904	12,282	-472	38%	56%	0%	834	964	704	2,501	2,891	2,111
4	5,904	12,282	-472	37.94%	56%	0%	625	723	528	2,501	2,891	2,111

3. HL vessel

a. Number of trips/month

Change in the number of the trips/month	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-6	4,705	7,688	1,721	41%	56%	24%	973	1,124	822	973	1,124	822
-4	6,007	9,403	2,614	49%	65%	31%	1,096	1,267	925	1,096	1,267	925
-2	7,311	11,120	3,507	56%	74%	37%	1,218	1,410	1,026	1,218	1,410	1,026
0	8,616	12,830	4,402	63%	82%	43%	1,341	1,553	1,129	1,341	1,553	1,129
+2	9,920	14,544	5,295	71%	91%	49%	1,463	1,695	1,231	1,463	1,695	1,231
+4	11,223	16,257	6,189	78%	100%	54%	1,586	1,838	1,334	1,586	1,838	1,334

b. Fuel/trip

Change in fuel/trip (litres)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-3	10,548	14,464	6,629	70%	87%	52%	1,434	1,646	1,222	1,434	1,646	1,222
-2	9,907	13,922	5,884	68%	85%	49%	1,403	1,615	1,191	1,403	1,615	1,191
-1	9,258	13,377	5,145	66%	84%	46%	1,372	1,584	1,160	1,372	1,584	1,160
0	8,616	12,830	4,402	63%	82%	43%	1,341	1,553	1,129	1,341	1,553	1,129
+1	7,973	12,286	3,659	61%	81%	40%	1,310	1,522	1,098	1,310	1,522	1,098
+2	7,327	11,739	2,918	59%	79%	37%	1,279	1,491	1,067	1,279	1,491	1,067
+3	6,686	11,195	2,176	57%	78%	33%	1,247	1,459	1,035	1,247	1,459	1,035
+5	5,397	10,103	691	52%	75%	24%	1,185	1,397	974	1,185	1,397	974
+10	2,179	7,377	-3,021	40%	66%	0%	1,030	1,241	818	1,030	1,241	818

c. Fuel price

Change in fuel price (Rp)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
0	8,616	12,830	4,402	63%	82%	43%	1,341	1,553	1,129	1,341	1,553	1,129
+2,000	6,737	11,241	2,237	57%	78%	33%	1,250	1,462	1,038	1,250	1,462	1,038
+4,000	4,859	9,646	72	50%	73%	6%	1,159	1,371	947	1,159	1,371	947
+6,000	2,982	8,056	-2,094	43%	68%	0%	1,068	1,280	856	1,068	1,280	856
+8,000	1,101	6,464	-4,258	34%	63%	0%	978	1,190	766	978	1,190	766
+10,000	-777	4,875	-6,426	0%	58%	0%	887	1,099	675	887	1,099	675

d. Catch/trip

Change in catch/trip (kg)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-5	3,068	6,601	-467	36%	54%	0%	924	1,085	763	924	1,085	763
-4	4,177	7,848	507	42%	60%	17%	1,007	1,178	836	1,007	1,178	836
-3	5,288	9,092	1,479	48%	66%	26%	1,091	1,272	910	1,091	1,272	910
-2	6,397	10,341	2,454	53%	71%	32%	1,174	1,365	983	1,174	1,365	983
-1	7,505	11,586	3,430	58%	77%	38%	1,257	1,459	1,055	1,257	1,459	1,055
0	8,616	12,830	4,402	63%	82%	43%	1,341	1,553	1,129	1,341	1,553	1,129

e. Fish price

Change in fish price (Rp)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-10,000	-966	2,116	-4,045	0%	30%	0%	621	747	495	621	747	495
-8,000	949	4,257	-2,355	22%	42%	0%	765	908	622	765	908	622
-6,000	2,865	6,402	-664	35%	53%	0%	909	1,069	749	909	1,069	749
-4,000	4,783	8,544	1,022	45%	63%	22%	1,053	1,231	875	1,053	1,231	875
-2,000	6,699	10,686	2,713	54%	73%	34%	1,197	1,392	1,002	1,197	1,392	1,002
0	8,616	12,830	4,402	63%	82%	43%	1,341	1,553	1,129	1,341	1,553	1,129

f. Owner's share

Change in owner's share (%)	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-18%	-1,196	1,850	-4,249	0%	28%	0%	1,710	1,980	1,440	603	698	508
-13%	1,477	4,844	-1,888	26%	45%	0%	1,609	1,863	1,355	805	932	678
-8%	4,155	7,840	470	42%	60%	17%	1,508	1,746	1,270	1,006	1,165	847
-3%	6,831	10,835	2,831	55%	73%	34%	1,408	1,630	1,186	1,207	1,398	1,016
0%	8,616	12,830	4,402	63%	82%	43%	1,341	1,553	1,129	1,341	1,553	1,129

g. Number of Fishers

Change in the number of fishers	NPV (£)			IRR			Fishers' income (£)			Owner's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
Only owner	44,304	52,755	35,855	216%	251%	180%	0	0	0	4,023	4,658	3,388
1	17,536	22,811	12,262	103%	125%	80%	2,011	2,329	1,693	2,011	2,329	1,693
2	8,616	12,830	4,402	63%	82%	43%	1,341	1,553	1,129	1,341	1,553	1,129
3	4,155	7,840	470	42%	60%	17%	1,006	1,165	847	1,006	1,165	847

4. LF vessel

a. Number of trips/month

Change in the number of the trips/month	NPV (£)			IRR			Owner's income (£)			Skipper's income (£)			Fishers' income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-6	41,503	92,086	-3,539	35%	59%	4%	9,251	12,346	6,495	1,144	1,488	838	714	827	601
-4	53,588	111,374	2,155	42%	69%	9%	10,355	13,870	7,226	1,285	1,676	937	802	931	673
-2	65,672	130,660	7,845	49%	79%	15%	11,459	15,395	7,957	1,425	1,909	994	891	1,036	746
0	77,759	149,951	13,533	56%	89%	20%	12,563	16,920	8,687	1,566	2,050	1,135	979	1,139	819
+2	89,846	169,245	19,225	62%	98%	25%	13,666	18,443	9,417	1,707	2,238	1,235	1,067	1,243	891
+4	101,933	188,534	24,915	69%	108%	30%	14,770	19,968	10,148	1,848	2,426	1,334	1,156	1,348	964
+6	114,020	207,825	30,602	75%	117%	34%	15,874	21,492	10,878	1,988	2,612	1,433	1,244	1,451	1,037

b. Fuel/trip

Change in fuel/trip (litres)	NPV (£)			IRR			Owner's income (£)			Fishers' income (£)			Skipper's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-3	107,200	174,388	47,422	66%	96%	38%	14,191	18,548	10,316	1,127	1,287	967	1,617	2,101	1,186
-2	97,386	166,240	36,125	63%	94%	33%	13,649	18,005	9,773	1,078	1,238	917	1,600	2,084	1,169
-1	87,573	158,099	24,830	59%	91%	27%	13,106	17,462	9,230	1,028	1,189	868	1,583	2,067	1,152
0	77,759	149,951	13,533	56%	89%	20%	12,563	16,919	8,687	979	1,139	819	1,566	2,050	1,135
+1	67,951	141,808	2,238	52%	86%	10%	12,020	16,376	8,144	930	1,090	770	1,549	2,033	1,119
+2	58,138	133,663	-9,058	48%	83%	-11%	11,477	15,833	7,601	881	1,041	720	1,533	2,017	1,102
+3	48,324	125,518	-20,351	44%	81%	0%	10,934	15,290	7,058	831	992	671	1,516	2,000	1,085
+4	38,512	117,375	-31,652	40%	78%	0%	10,391	14,747	6,515	782	942	622	1,499	1,983	1,068
+5	28,698	109,230	-42,945	35%	75%	0%	9,848	14,204	5,972	733	893	573	1,482	1,966	1,051
+6	18,887	101,085	-54,242	30%	72%	0%	9,305	13,662	5,429	684	844	523	1,465	1,949	1,035
+7	14,926	98,405	-59,344	27%	72%	0%	9,115	13,471	5,239	634	795	474	634	795	474
+8	5,950	91,043	-69,755	20%	69%	0%	8,622	12,979	4,747	585	745	425	585	745	425
+9	-3,026	83,678	-80,166	0.00%	67%	0%	8,130	12,486	4,254	536	696	376	536	696	376

c. Fuel price

Change in fuel price (Rp)	NPV (£)			IRR			Owner's income (£)			Skipper's income (£)			Fishers' income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
0	77,759	149,951	13,533	56%	89%	20%	12,563	16,920	8,687	1,566	2,050	1,135	979	1,139	819
+1,000	64,372	138,528	-1,599	50%	85%	4%	11,807	16,164	7,931	1,488	1,972	1,057	927	1,087	767
+2,000	50,984	127,103	-16,735	45%	81%	0%	11,051	15,408	7,175	1,410	1,894	979	875	1,035	715
+3,000	37,595	115,678	-31,874	39%	77%	0%	10,296	14,653	6,420	1,332	1,816	901	823	983	663
+4,000	24,204	104,255	-47,008	32%	73%	0%	9,540	13,897	5,664	1,254	1,738	823	770	930	610
+5,000	10,818	92,826	-62,144	24%	69%	0%	8,784	13,141	4,908	1,177	1,661	746	718	878	558
+6,000	-2,571	81,402	-77,282	-21%	65%	0%	8,029	12,386	4,153	1,099	1,583	668	666	826	506

d. Catch/trip

Change in catch/trip (kg)	NPV (£)			IRR			Owner's income (£)			Skipper's income (£)			Fishers' income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-20	890	52,576	-45,267	8%	43%	0%	6,786	9,634	4,243	924	1,241	642	498	600	397
-15	20,107	76,956	-30,593	25%	55%	0%	8,230	11,455	5,354	1,085	1,443	765	618	735	502
-10	39,324	101,305	-15,897	36%	67%	-14%	9,674	13,277	6,465	1,245	1,645	889	739	870	608
-5	58,543	125,636	-1,187	46%	78%	6%	11,119	15,098	7,576	1,406	1,848	1,012	859	1,004	713
0	77,759	149,951	13,533	56%	89%	20%	12,563	16,919	8,687	1,566	2,050	1,135	979	1,139	819

e. Fish price

Change in fish price (Rp)	NPV (£)			IRR			Owner's income (£)			Skipper's income (£)			Fishers' income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-2,500	-14,265	35,325	-58,384	-12%	34%	0%	5,647	8,305	3,283	798	1,093	535	445	542	347
-2,000	4,139	58,251	-43,997	12%	46%	0%	7,030	10,028	4,364	951	1,284	655	551	662	441
-1,500	22,543	81,174	-29,612	26%	57%	-26%	8,413	11,751	5,445	1,105	1,476	775	658	781	536
-1,000	40,950	104,100	-15,233	37%	68%	-13%	9,797	13,473	6,525	1,259	1,667	895	765	901	630
-500	59,353	127,026	-848	47%	78%	6%	11,180	15,196	7,606	1,412	1,859	1,015	872	1,020	724
0	77,759	149,951	13,533	56%	89%	20%	12,563	16,919	8,687	1,566	2,050	1,135	979	1,139	819

f. Owner’s Share

Change in owner's share (%)	NPV (£)			IRR			Owner's income (£)			Skipper's income (£)			Fishers' income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
-10%	67,290	136,902	5,353	51%	83%	13%	11,776	15,939	8,072	779	1,069	521	1,162	1,344	980
-5%	72,522	143,429	9,446	53%	86%	17%	12,169	16,429	8,379	1,173	1,560	828	1,071	1,242	900
0%	77,759	149,951	13,533	56%	89%	20%	12,563	16,920	8,687	1,566	2,050	1,135	979	1,139	819

g. Number of Platforms

Change in the number of platforms	NPV (£)			IRR			Owner's income (£)			Skipper's income (£)		
	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic	Common	Optimistic	Pessimistic
6	-15,569	199,871	44,829	-13%	111%	39%	8,423	17,118	10,107	710	1,066	558
7	7,565	181,692	33,434	15%	103%	33%	9,502	17,097	9,838	938	1,321	731
8	31,043	168,587	25,217	32%	97%	28%	10,505	16,962	9,204	1,142	1,539	783
9	54,622	158,543	18,923	44%	92%	24%	11,484	16,941	8,868	1,337	1,795	933
10	77,759	149,951	13,533	56%	89%	20%	12,563	16,919	8,687	1,566	2,050	1,135

Appendix O. Inventory analysis for S-LCA

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
Workers (fishers/skippers, port-based workers).	Freedom of association and collective bargaining.	Fishers are not conditioned by any restrictions on the right to collective bargaining.	1. The relationship between the owner and the fisher has been built based on trust and the nature of collaboration is a mutual need. Therefore, both fishers and owners have a strong bargaining position. For example, in PD vessels, typically, the owner decides to go or not to go fishing based on their financial situation. However, occasionally the decision is driven by the skipper on behalf of the fishers due to their financial demand. As one of the owners said, *"When they came to me asking for money, what could I do? I had to help them even though I did not have so much left."* The owner is aware that fishers play an essential role in their business. Therefore, even with all the limitations they might have, the owner will help and support the fishers as much as he can. 2. Fishers/skippers can negotiate their share, although it is not going to be significantly different to the ones that are commonly applied. In the focused group discussion (FGD) with the workers, it was revealed that the sharing system was changed several years ago on some vessels, due to consideration of the inflation rate.	1. Indonesian Constitution 1945. Article 28 regarding freedom of association and collective bargaining, which is regulated by law 2. The regulation of the Ministry of Fisheries and Marine Affairs No 35/Permen-KP/2015 (on) the System and Certification of Human Rights in the Fisheries Industry.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			3. Regarding local government and port authority, the remaining fishers are free to discuss their aspirations which are typically represented on behalf of fishers' unions.	
		The presence of unions.	1. The National Fishers' Association (HNSI) was established in 1973 (HNSI, 2012). Its mission is to strengthen fishers' influence on the national development framework, besides accommodate their aspirations. Its branches are distributed throughout Indonesia, including Palabuhanratu. The organisation plays a significant role in the community, although it is more involved in politics than social actions. 2. There are also fisher working groups, which are typically classified based on the fishing gear types. The groups are encouraged by the government for empowerment reasons.	Regulation of the Ministry of Marine Affairs and Fisheries, No 2/PERMEN-KP/2013 (on) The Guidelines for National Fisheries Empowerment
		Fishers are free to join unions of their choosing.	Fishers are free to join the association and working group.	Regulation of the Ministry of Fisheries and Marine Affairs No 35/Permen-KP/2015 (on) the System and Certification of Human Rights in the Fisheries Industry
	Child labour.	The absence of working children under 18 years of age.	1. The legal age for the workforce is 18 years old. However, some young fishers involved in the FGD admitted that they had left school or finished primary education and been a crew member from the age of 12. 2. Some children work in the fishing port on a daily basis. They help the fishers to unload the fish or pick up the scattered fish. They have left school due to financial and family	1. Indonesian Law, No 13 of 2003 (on) Employment, Article 1, Point 26 regarding the definition of children is those who are less than 18 years old

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			reasons and they work individually. The fishers allow them to work for empathic reasons. 3. Interview with the youth group (11 – 17 years old) confirmed that about 26.7% of respondents are going to sea during the weekend either to help their parents or just to relax. The youths who are going to sea are those who come from fisher families.	2. Indonesian Law, No 13 of 2003 (on) Employment, Article 68 – 75 concerning employment of children.
	Fair salary.	Income from fishing compared to the minimum wage.	1. Fishers in Palabuhanratu do not receive a fixed salary but a shared income. 2. The percentage that is shared is allocated based on local wisdom by considering the amount they deserve. A little adjustment can be made through an agreement between workers and the owner. 3. Regarding the owner's share, the highest percentage is found in the TN vessel, followed by the LF, HL and the PD vessels. Furthermore, in terms of fishers' share, the largest percentage is found in the HL vessel, followed by the TN, LF and the PD vessels. 4. Despite the small share, all the respondents from the fisher groups are content with the applied sharing system. It was also confirmed by the housewives and youth groups. 5. Based on annual profit analysis, the fishers' net income ranges from 834 GBP to 1566 GBP per year. Compared to the regional standard wage, which is 1406 GBP per year, the fishers' income is relatively low.	1. Indonesian Law, No 16 of 1964 (on) the Fisheries Sharing System. Chapter 2 concerns the principal of the sharing system. 2. Decree of West Java Governor, No. 561/Kep. 1581 – Bangsos/2014 (on) minimum regional wage. The regional minimum wage for the regency in 2015 was 1406 GBP.
	Working hours.	Decent working hours.	1. Generally, fishers do not have fixed working hours and working days, as it is highly dependent on the fish seasons, weather and sometimes the availability of operational costs.	Regulation of the Minister of Manpower and Transmigration, No.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			2. Fishers from the studied vessel typically work for 14 hours/day, either conducting day or night fishing. When they perform day fishing they will leave the port around 4 am and be back to the port around 6 pm. In reverse, if they undertake night fishing, they will leave the port around 4 pm and be back to the port at 6 am approximately. 3. They might have a more extended trip (more than one day) occasionally. In this case, even though they go to fishing grounds further away, they will stay overnight at the nearest quay/marina and undertake a one-day trip from that place. 4. For typical PD and TN vessels, Friday is the day off fishing due to religious reasons (Friday prayers). However, it is not a strict rule. Some fishers will keep fishing if there is a lot of fish. 5. The TN vessel is operated in a passive method for few months. During that time, the operational time is only 2-3 hours/day. 6. For a typical HL vessel, they can go fishing throughout the year following the fish seasons. Most of operation is conducted during the night-time, yet it can be done during the day-time. When operated during the day-time, the working hours is usually reduced to 5-7 hours due to the weather issue. 7. For a typical LF vessel, the full moon is when fishing is break off. The bright moonlight prevents fish from gathering under the light installed on the platform. While the gear is being operated, the fishers have a chance to take a rest, as the gear is soaked for about 2-3 hours.	PER.24/MEN/VI/2006 (on) Social Security for Non-contractual employment. Chapter 1 related to the characteristics of non-contractual employment.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			8. They are content with their working hours. If they feel tired/sick/have other business, they can have a day off, but as a consequence, they will not be paid. 9. Amongst the studied vessels, the most decent working hours is in the LF vessel, followed by the TN, HL and the PD vessels.	
	Forced labour.	Workers voluntarily agree the employment terms.	1. Participation in fishing operations is voluntary. Typically, a newcomer who joins the operation has a family or friend who knows the vessels' crew or the owner. 2. Most fishers admitted that they were not forced to become a fisher. However, regarding employment they had no other choices open to them. 3. Work as a fisher is considered non-contractual employment. Hence, there is no legal agreement between the worker and the employer. Their relationship has been built based on trust, social norms and a mutual need. 4. However, via the most recent law on protection for the fishers, the government has encouraged both employers and fishers to produce a written contract concerning employment or the sharing system.	Indonesian Law No. 7 of 2016 (on) Protection and Empowerment for fishers, fish farmers and salt farmers. Article 28, regarding the employment contract.
		Worker are free to terminate their employment within the usual time.	1. Basically, fishers are free to terminate their involvement in one vessel and move to another one owned by a different person. However, it is common knowledge that they should do it appropriately without leaving any debts or personal issues. 2. When someone is moving, the future employer will confirm the fishers' status by checking their collaboration history with the previous vessel before accepting them. This is done in order to avoid future conflicts.	Regulation of the Ministry of Fisheries and Marine Affairs No 35/Permen-KP/2015 (on) the System and Certification of Human Rights in the Fisheries Industry. Article 5b concerning rights for fair and decent working conditions.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
		The worker is not bonded by debts to the employer exceeding legal limits.	1. Typically, the fishers take loans either from the owner or the seller. Regarding this, it can be said that the presence of debt indicates collaboration between them. 2. There is no legal limit for debts. However, typically the amount of debt is not significantly higher than their ability to pay it off. This is because during the peak season the fishers generally will pay the debt, though they create additional debt during the low season.	Regulation of the Ministry of Fisheries and Marine Affairs No 35/Permen-KP/2015 (on) the System and Certification of Human Rights in the Fisheries Industry. Article 5b regarding rights for fair and decent working conditions.
	Equal opportunities	Women in the labour force.	1. In Palabuhanratu, a fisher is the type of job which women, in general, are not involved in, especially in the fish catching process. However, women participate in pre and post fishing as owners, sellers, fish buyers, fish processors or vendors. 2. There is no data showing the percentage of women involved in the fishing related business. However, some women are involved in the value chain and have the same opportunities as men.	Regulation of the Ministry of Fisheries and Marine Affairs No 35/Permen-KP/2015 (on) the System and Certification of Human Rights in the Fisheries Industry. Chapter 2, Article 5 Human rights system in fisheries.
		Presence of discrimination.	1. 100% of the respondents confirmed that there is no discrimination among fellow crew, fishers and community members. 2. As vessel crew, they hold the same rights and receive equal treatment from the employer. Meanwhile, as citizens, fishers have the same access to public services and facilities as other community members. 3. However, some fishers said that the performance of the fishers' association (HNSI) is not satisfactory in	1. Regulation of the Ministry of Fisheries and Marine Affairs No 35/Permen-KP/2015 (on) the System and Certification of Human Rights in the Fisheries Industry. Article 5b about rights for fair and decent working conditions.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			accommodating the small-scale fishers' aspirations as most of the benefits only partially affect the fisher community.	2. Article of Association of the HNSI
	Health and safety.	Frequency of occupational accidents.	1. The number of accidents that fishers have been involved in is not recorded. An accident report is written by the local police, however, the data includes local tourists. The police confirmed that the fishers are rarely involved in accidents, as stated during the interview. *"Roughly two or three cases in the last 5 years."* 2. Regarding the fishers, 36.7% of the respondents confirmed that they had an accident while working at sea. The most common accident experienced by the fishers was suffering a from a hook and getting a sprain when hauling the nets. One hand lining fisher stated that he had been burnt in 2008 when a lamp exploded. During that time he used a kerosene lamp fuelled by petrol. Another experience was capsizing which happened during rough weather. However because most of the fishers can swim, even all of the respondents are capable of swimming, most of the fishers from the capsized boat survived. 3. Narrowing down the survey, amongst the studied vessels, the LF vessel is the operation with no accident record, whilst in the PD, TN and HL vessels, about 25%, 57% and 71%	Frequency and severity index suggested by IMO.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			respondents in respective order confirmed that they had an accident when conducting a fishing operation. 4. Approximately 96.7% of respondents agreed that accidents especially the serious ones like burning and capsizing are rare, whilst the rest of the respondents said they never seen any accidents whilst working at sea. 5. Regarding the local community, approximately 96.4% of the housewife respondents also confirmed that they rarely heard of accidents at sea, while the remaining respondent have never heard of any. There was a recent case however when a boat capsized leading to the death of an individual. 6. All the young respondents and stakeholders involved in pre and post fishing confirmed that they rarely heard about accidents at sea.	
		Prevention and handling measures.	1. There is virtually no safety equipment on the vessels. If a fisher falls into the water, he will only rely on his ability to swim and plastic containers, which are commonly used as emergency floats. 2. The vessels do not have first aid kits. Fishers will bring their own medicine such as ointment or paracetamol if they are aware that they will need them during operational time. 3. In the port, the water police provide assistance if an accident occurs and evacuate the victim. 4. A small clinic is situated inside the fishing port area, which opens 5 days a week from 8 am – 2 pm. Other more prominent clinics and the hospital are located outside the port. Some have 24 hour access.	1. Regulation of the Ministry of Fisheries and Marine Affairs No 35/Permen-KP/2015 (on) the System and Certification of Human Rights in the Fisheries Industry. Assurances about the right to security and safety. 2. Indonesian Law No. 7 of 2016 (on) Protection and Empowerment for fishers, fish farmers and

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
				salt farmers. Article 40 about the security and safety for fishers. 3. Regulation of the Ministry of Transportation No KM 65/2009 (on) Standard for Non-Convention Vessels
	Social benefit/social security.	Social benefits provided to the fishers.	1. Indonesian government provides health insurance for all citizens including fishers. However, the health insurance provided for fishers is general health insurance for citizens and not specifically for fishers. 2. As non-contractual employment, fishers are not associated with any company. Therefore there is no occupational accident insurance and life insurance for them. The fisher insurance programme provided by the Ministry of Fisheries and Marine Affairs is still in the implementation process. However, the local government claimed that they have provided fishers with health insurance (Fikri, 2017). 3. The Ministry of Fisheries and Marine Affairs provides a fisher card to optimise fisher protection and the empowerment programme. By using the fisher card, fishers have access to all the facilities, grants and subsidies provided by the government.	Indonesian Law No. 7 of 2016 (on) Protection and Empowerment for fishers, fish farmers and salt farmers. Chapter V, Article 30 - 35, regarding Social security. The government is responsible for providing assurances relating to the security and safety of the fishers.
Value chain actors (vendors, owners, sellers, fish	Fair competition.	Documented statement or procedures to prevent engaging in or	1. There is no documented or legal procedures in the community which ensures fair competition amongst value chain actors. The strong religious belief in predestined luck in the business	Indonesian Law, No 45 of 2004 (on) Amendment of Law No 31 (on) Fisheries

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
buyers, second-hand goods buyers).		being complicit in anti-competitive behaviour.	has driven fair competition amongst the actors. Furthermore, social norm controls attitude and business behaviour. 2. Palabuhanratu is open for those who want to run a fisheries-related business. To operate a small-scale business, a licence is required from the local government. If the business is run inside the fishing port an additional licence is also required from the fishing port. Therefore, as long as the requirement is met, the new actor can enter the business easily. 3. Typically, no legal contract is applied in the collaboration between the value chain actors. The actors are free to choose their business partners. However, family relationships and financial reasons such as payment flexibility and price might affect their preferences.	Article 2 concerning the basic principles of fisheries management such as benefit, fairness, partnership, independence, equality, and integration. Therefore, the government should manage the business circumstances to comply with the law.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
	Relationship with suppliers.	The strength of the relationship between the fishing vessel owners and vendors.	1. Small-scale fishing operations do not need a regular purchase in large quantities. The typical relationship between owners and vendors is just a common relationship between the buyer and the seller. 2. The basic requirement for fishing operations is fuel and ice. Fuel is solely supplied by a national oil company, whilst ice can be bought from depots run by resellers who are supplied by two major producers in the region. Both fuel stations and ice depots are located in the fishing port area. 3. Several fishing equipment and electronic stores are located near the fishing port, providing items which are not purchased on a daily basis, such as fishing gear, lamps and plastic containers. 4. The vessel is made by order and its maintenance is performed periodically. The collaboration with the builder is only when a new vessel is ordered and when heavy maintenance is required. The owner does not necessarily collaborate with the same builder. 5. According to Tangpong *et al.* (2015), the type of buyer-supplier relationship that is applied in the studied system is based on free will/voluntary relationship. The buyer independently collaborates with suppliers, who are only supporting essential requirements on an ongoing basis.	No reference point is found regarding the ideal buyer-supplier relationship in the small-scale fishing business. However, the respondents confirmed that they are happy with the existing relationship between the value chains in the fishing operations.
Local community (fishers' wife, youth, non-fishing workers).	Delocalisation and migration.	Evidence of migration due to fishing activities.	1. Palabuhanratu is located in West Java Province and is inhabited by the Sundanese. However, now the composition of migrant fishers and local fishers has changed. The ethnicity of fishers can be divided into three groups: Sundanese, Buginese and Javanese. Even though the largest ethnicity is Sundanese,	The model proposed by Miller (1982), showed that fishing activities encourage migration.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			the remaining ethnicity also plays a vital role in fisheries development in Palabuhanratu. 2. The Buginese migrated to Palabuhanratu in the 1960's due to safety issues as well as their character as sailors. They introduced lift net fishing which later on developed into one of the popular fishing gears in the region. Following their ancestors, most lift net fishing is now operated by the Buginese. 3. Trammel net fishing is also evidence of migration and the adaptation of technology. Trammel net fishing was introduced by the Sundaneses who are from the northern coast of Java Island and migrated to Palabuhanratu which is located on the southern coast. Although the development is not as significant as lift nets, this fishing unit plays an important part as the most reliable prawn fishing in the region. Similar to lift net fishers, most trammel net fishers are also migrants. 4. Further evidence of the migration is the phenomenon of nomad fishers. Nomad fishers are predominantly from larger vessels (longliner/gillnetter/purse seiner) which only stay short-term in Palabuhanratu before leaving on another trip. Those fishers are mostly Javanese. 5. The development of the fishing port in Palabuhanratu also affects economic growth as different types of business and job opportunities emerge and attract more people to migrate, especially from rural areas around Palabuhanratu. 6. Regional statistics reveals that in 2015, 217 people moved in, whilst 75 people moved out (The Government of Palabuhanratu District, 2016)	

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
	Community engagement.	The diversity of community stakeholder group that engages with fishing activities.	1. Fishing activities in Palabuhanratu relate to different types of community members from fishing to non-fishing related backgrounds, such as boat builders, fish traders, seafood producers, fishing boat rental, a teacher in the vocational fisheries school, general traders and restaurant entrepreneurs. 2. By number, the PD vessel engages more people than other vessels, it is followed by the LF, HL and TN vessels. 3. The communities both from inner and outer Palabuhanratu rejoice in celebrating the National Fishermen's Day every 6th April.	Indonesian Law, No 31 of 2004 (on) Fisheries. Article 6 (2) about the requirement to respect local wisdom and community engagement. Article 60 about engaging diverse fishing communities.
	Cultural heritage.	Presence of traditional ceremony.	1. Every 6th of April the fishers in Palabuhanratu hold a traditional ceremony to show respect to their ancestors by offering sacrificial objects such as bullheads and food for the goddess of the sea. This event has been held since the 15th century (MMAF, 2016). Due to its popularity, it was later recognised as National Fishermen's Day which in 2017 became the 57th national celebration. 2. The ceremony is considered an important event in the region. The chief for the ceremony is a prestigious position. He is elected through the fishers voting forum.	Indonesian constitution 1945, Article 18B concerning recognition and respect for traditional rights.
	Respect for indigenous rights.	The strength of policies in place to protect the rights of indigenous community members.	1. In accordance with the international convention, fisheries law in Indonesia also protects traditional fishing practice. 2. The recognition of the traditional ceremony, National Day showed that cultural heritage in Palabuhanratu is strongly appreciated and protected not only by the local people but also the government.	Indonesian Law, No 31 of 2004 (on) Fisheries. Article 6 (2) about the requirement to respect local wisdom and community engagement.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
	Local employment.	Percentage of workforce hired locally.	100% of fishers working in the studied operations are local people, despite their different ethnicities. There is no data showing the fisher distribution based on ethnicity, however, generally there are four main groups: a. Southern coast Sundanese (indigenous people). Most work on HL and PD vessels. b. Northern coast Sundanese. Most work on TN vessels. c. The Buginese. Most work on LF vessels d. The Javanese. Most work on larger vessels on temporary stays.	Indonesian Law, No 31 of 2004 (on) Fisheries. Article 6 (2) about the requirement to respect local wisdom and community engagement.
		Percentage of spending on local vendors.	Most vendors are from Palabuhanratu. Even though items are occasionally not stored in Palabuhanratu, there will be a vendor representative in the region. Fibreglass boats are built in different areas located about 10 miles from Palabuhanratu. Furthermore, certain types of wood are also obtained from vendors outside Palabuhanratu.	
	Access to immaterial resources.	Presence of community education initiatives.	1. The empowerment programme has allowed the fishers' wives to have access to immaterial resources such as mentoring, supervision and workshops in the fisheries development corridor. 2. Fishing activity has encouraged the youth to study in the vocational fisheries school established in Palabuhanratu, which offer diverse majors such as nautical studies, fishing technology and fish processing technology.	1. Indonesian Law No. 7 of 2016 (on) Protection and Empowerment for fishers, fish farmers and salt farmers. Article 45 about women empowerment. Article 46 concerning fishers empowerment including their family.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
	Access to material resources.	Extraction of material resources.	1. Both fishing and non-fishing communities have the same access to material resources, such as fish and subsidised fuel. 2. Everyone is free to catch fish, either as a hobby or for money. People can fish around the fishing port or hire a boat. They are allowed to work on-board as long as the vessel's crew/owner gives permission. **A non-fisher attendee** is typically found joining in lift net fishing. 3. Regarding access to fuel, there are three fuel stations located near the fishing port, one is for the public customer and the other two are for fishers. The larger stations are provided in order to make it easier for fishers to buy fuel in large quantities using portable fuel tanks. Excluding that, the fuel is sold at the same price. 4. According to the fishing inputs, the TN vessel use the largest inputs, followed by HL, PD and LF vessels. Both the PD and LF vessels use the same amount of fishing inputs.	Indonesian Law, No 31 of 2004 (on) Fisheries. Article 61 about rights for small-scale fishers to conduct fishing.
	Safe and healthy living conditions.	Neighbourhood environment	1. According to the regional statistics report, approximately 37% of residents are living in poverty, most are fishers (The Government of Palabuhanratu District, 2016). Poverty can be associated with poor housing and conditions at home, hence, it can be said that fisheries activity directly impacts on living conditions in the region. 2. The fishers mostly live in the area within 5 km of the fishing port. There are two types of neighbourhood: mixed and the fisher's neighbourhood. 3. The mixed neighbourhood is the place where fishers live with various community members in the permanent residential area either in the town centre or the nearest villages. In the town	1. Decree of the Ministry of Housing and Infrastructure No 534/KPTS/M/2001 (on) standard of minimum service for urban and rural housing. 2. Regulation No 14 of 2016 (on) Housing and Settlement Areas.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			centre, they live a densely populated area with limited access to clean water and an inadequate sanitation system. However, in the villages, the fishers live in more spacious areas with proper sanitation and better quality water. 4. The fishers' neighbourhood is a semi-permanent residential area built by the fishers. It is situated next to the fishing port, so fishers have straightforward access to their vessels. The area was built on a field that used to be owned by a national oil company. The houses are typically small, approximately 21-36 m^2, with poor water and sanitation systems. Toilets are not available in every house, but there is a public toilet which is accessible for residents. 5. The Government of Palabuhanratu District (2016) also claimed that 25% of households in Palabuhanratu used shared or public toilets	
	Secure living conditions.	Presence of security issues related to fishing activities.	1. In correlation with the impact of fishing activities, respondents from the non-fishing community confirmed that Palabuhanratu is relatively a safe place to run a fishing business. It is a non-violent area with few criminal incidents. However, trust can be a serious issue, especially for people from outside Palabuhanratu who want to start a fishing business, as it is not easy to find reliable partners. 2. The fishing port area is generally safe, as there is a 24 hour security service. No serious issues are observed relating to the presence of nomad fishers, who stay in their boats during their visit.	1. Decree of the Ministry of Housing and Infrastructure No 534/KPTS/M/2001 (on) standard of minimum service for urban and rural housing. 2. Indonesian Law No. 7 of 2016 (on) Protection and Empowerment for fishers, fish farmers and salt farmers. Article 40

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			3. Outside the port, there are some criminal cases, such as theft and offensive acts, however, it is challenging to deduce that it is solely driven by the fisheries sectors.	concerning security and safety for fishers.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
Society (the government, influential figures).	Public commitment to sustainability issues.	Presence of actions related to sustainability promotion.	1. The existence of an annual ceremony since the 15th century is proof that they have a firm commitment to preserving the tradition. 2. The sharing system is part of the social norm, which the fishing community will follow as it is. Once agreed, the sharing percentage tends to remain constant, unless a significant change occurs, such as an increase in operational costs and the inflation rate. 3. Within the community, it is strongly believed that Palabuhanratu bay will not be overfished as long as the marine environment is adequately maintained. Therefore, fishers take action when they discover fishing activities which damage the environment, such as explosive fishing and trawl fishing. However, regarding the protection of certain species, some fishers and value chain actors are reluctant to follow the regulations, due to existing market demands. For example, there is a regulation to protect certain valuable species, such as sharks, stingrays and juvenile lobsters. Even though the fishers might be aware that catching those species damages the ecosystem, the financial reasons actively drive their actions. In this case, government surveillance and community control are essential to prevent contraventions.	Indonesian Law, No 31 of 2004 (on) Fisheries. Article 61: small-scale fishers are free to conduct fishing operations, however, they have to preserve the environment.

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
	Prevention and mitigation of conflict.	Level of existing conflict.	Conflict typically happens in Palabuhanratu: 1. Conflict between fishers using the same fishing gear**,** such as fighting for fish in the same fishing ground. Most likely happens in Pelagic Danish Seine fishing. 2. Conflict between fishers using different fishing gear**,** such as conflict because of a crash in the fishing port, jealousy due to fishing domination and personal matters. 3. Vertical conflict between fishers and association, where the fishers, including the owners, feel that the association is not representing their interests as expected. However, even with all the current conflict, the dynamic of the fisher community in Palabuhanratu remains under control. Palabuhanratu is a safe region where the fishers and other community members live in harmony.	Follow the level of intensity suggested by the Heidelberg Institute for International Conflict Research.
		Conflict management.	Fishers are aware that confrontation might have negative impacts on the community and it is an inappropriate action. Therefore when something happens out of their expectations, they will seek to understand the situation and leave it as it is. However, if the problem is difficult to resolve, they will ask a third party, such as local government, the police, association or influential figures to mediate the conflict.	1. Code of conduct for responsible fisheries. Article 7.6.5: States, “fisheries management organisations and arrangements should regulate fishing in such a way as to avoid the risk of conflict among fishers using different vessels, gear and fishing methods.”

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
				2. The philosophical foundation of Indonesia (Pancasila)
	Contribution to the economic development.	Contribution to regional economic.	1. Palabuhanratu is considered one of the primary fisheries business centres in Indonesia. According to The Government of Palabuhanratu District (2016), approximately 28% of the productive workforce in the region is working in the fisheries sector performing a wide range of jobs, such as fishers, boat builders, suppliers and fish traders. In addition, 65% of households are related to the marine fisheries sector. 2. A regional economic report in 2013 showed that the fisheries sector together with agriculture and forestry were responsible for a significant amount of the regional income, which constitutes 23% (Centre for Statistics of Sukabumi Regency, 2016). 3. Narrowing down the scope, the contribution to the regional economic can be seen from the value of fish production. Compared to other vessels, the LF vessel produce the highest value, followed by the PD, HL and TN vessel.	Indonesian Law, No 31 of 2004 (on) Fisheries: Fisheries play a vital and strategic role in national economic development.
	Free from corruption.	Presence of actions to prevent corruption.	1. Corruption is an important issue. It can relate to either government at the policy level or fisheries' actors at the practical level. In government organisations, preventive actions have been taken seriously, in the form of regulation and monitoring systems. 2. Regarding the practical level, there are some fishing boat owners who keep their distance and collaborate with local partners to run their vessels. Partners who cannot be trusted might falsify the income reports and propose a larger	

Main Stakeholder group	Subcategories	Indicators	Status	Reference point
			operational budget. Furthermore, an inexperienced player might also be deceived by a promising projection of fishing profit, which omits certain facts, such as maintenance cost and seasonal effects. Distant owners and new players should find a reliable partner and conduct continuous monitoring in order to prevent corruption.	
	Development of technology.	Involvement in technology transfer programme or project.	1. The technology transfer programme will be successful in the fishing industry if the stakeholder is involved during the process. In 2008, there was a successful programme to change wooden boats to fibreglass boats, even though it was only possible for a small boat of less than 3 GT. Stakeholders have been involved since the design process. Generally, they are happy to be part of transfer technology, especially when this technology has the potential to save their money or increase their income. 2. When the survey was conducted, another technical development programme for converting fuel from petrol to LPG was in place.	Indonesian Law, No 31 of 2004 (on) Fisheries. Article 52 – 56 regarding research and development in fisheries.
		Partnership in research and development.	Fishers in Palabuhanratu are actively involved in various research activities, either short or long-term research.	

Appendix P. S-LCA calculation

Impact categories	Weight 1	Subcategories	Weight 2	Gap				Total score			
				PD	TN	HL	LF	PD	TN	HL	LF
Human right	0.17	Child labour	0.33	3.50	3.50	3.50	3.50	0.19	0.19	0.19	0.19
		Forced Labour	0.33	1.42	1.42	1.42	1.42	0.08	0.08	0.08	0.08
		Equal opportunity	0.33	1.00	1.00	1.00	1.00	0.06	0.06	0.06	0.06
Working condition	0.17	Freedom of association and collective bargaining	0.33	0.42	0.42	0.42	0.42	0.02	0.02	0.02	0.02
		Fair salary	0.33	4.50	3.75	4.25	4.00	0.25	0.21	0.24	0.22
		Working hours	0.33	1.00	0.50	0.75	0.25	0.06	0.03	0.04	0.01
Health and safety	0.17	Health and safety	0.50	2.38	2.50	2.63	2.25	0.20	0.21	0.22	0.19
		Social benefit/social security	0.50	1.25	1.25	1.25	1.25	0.10	0.10	0.10	0.10
Cultural heritage	0.17	Delocalisation and migration	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Community engagement	0.17	0.50	1.00	0.75	0.25	0.01	0.03	0.02	0.01
		Cultural heritage	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Respect of indigenous rights	0.17	0.25	0.25	0.25	0.25	0.01	0.01	0.01	0.01
		Access to immaterial resources	0.17	0.75	0.75	0.75	0.75	0.02	0.02	0.02	0.02
		Access to material resources	0.17	0.75	1.25	1.00	0.75	0.02	0.03	0.03	0.02
Socio-economic repercussion	0.17	Safe and healthy living condition	0.17	2.50	2.50	2.50	2.50	0.07	0.07	0.07	0.07
		Secure living condition	0.17	0.75	0.75	0.75	0.75	0.02	0.02	0.02	0.02
		Local Employment	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Prevention and mitigation of conflict	0.17	0.89	0.89	0.89	0.89	0.02	0.02	0.02	0.02
		Contribution to economic development	0.17	0.25	0.75	0.50	0.00	0.01	0.02	0.01	0.00
		Suppliers relationship	0.17	0.50	0.50	0.50	0.50	0.01	0.01	0.01	0.01
Governance	0.17	Public commitment to sustainability issues	0.25	1.00	1.00	1.00	1.00	0.04	0.04	0.04	0.04
		Technology development	0.25	0.44	0.44	0.44	0.44	0.02	0.02	0.02	0.02
		Free from corruption	0.25	0.67	0.67	0.67	0.67	0.03	0.03	0.03	0.03
		Fair competition	0.25	1.50	1.50	1.50	1.50	0.06	0.06	0.06	0.06

Appendix Q. Inventory analysis for alternatives for LF platform's base

1. Existing platform

Main characteristic	Unit	Detail
Platform		
Dimension	m	9 x 9
Volume Bamboo	m^3	5
Density	ton/m^3	0.73
Platform weight	ton	3.64
Drum		
Quantity	pcs	18
Height	m	0.99
Diameter	m	0.58

2. Proposed vessel's dimension

Drums to be replaced either with two smaller boats or 1 larger boat.

Specification	Unit	Smaller vessel	Larger vessel
LOA	m	9	11
Breadth	m	1.1	2
Depth	m	0.8	0.8

3. Inventory analysis for the vessels

Resources	Unit	Input		Lifetime
		Smaller vessel	Larger vessel	
1) Production				
Fibreglass	kg	350	1100	20 years
Antifouling	kg	3	6	
Electricity	kWh	40	130	
2) Maintenance				
Fibreglass	kg	15	55	3 years
Antifouling	kg	3	6	
Electricity	kWh	4	13	
3) End of life				
Incinerated	kg	111	350	
Landfilled	kg	260	817	

Appendix R. Inventory analysis for fibreglass conversion for PD vessel (only hull)

The proposed fibreglass vessel is the same dimension as the existing wooden vessel, i.e.

LOA = 12 m, B_{max} = 2.5 m, D = 0.8 m

1. Inventory analysis

Resources	Unit	Input	Lifetime	Waste treatment	
1) Production				**Incinerated**	**Landfill**
Fibreglass	kg	1000	20 years	30%	70%
Sawn wood	kg	530			
Reinforcing steel	kg	15			
Antifouling	kg	5			
Electricity	kWh	120			
2) Maintenance					
Fibreglass	kg	50	3 years	30%	70%
Sawn wood	kg	176			
Reinforcing steel	kg	5			
Antifouling	kg	5			
Electricity	kWh	24			

2. Maintenance cost breakdown (in Indonesian Rupiah, £1 = Rp 16,555)

Cost components	Unit	Period	Pervessel					Cost/ maintenance	Maintenance cost/year
			Quantity	Volume	Freq.	Sum (Q)	Cost/unit		
Fishing vessel									
1) Relaminating									
Resin	kg	Every 3 years	30.00	1.00	1.00	30.00	30,000	900,000	300,000
Fibreglass	kg	Every 3 years	20.00	1.00	1.00	20.00	30,000	600,000	200,000
Anti fouling	kg	Every 3 years	5.00	1.00	1.00	5.00	65,000	325,000	108,333
2) Replanking									
Wood	pcs	Every 3 years	9.00	1.00	1.00	9.00	100,000	900,000	300,000
Fastening	kg	Every 3 years	5.00	1.00	1.00	5.00	10,000	50,000	16,667
Labour	man-day	every 3 years	2	5	0.5	5	120,000	1,200,000	600,000
								Maintenance cost for FV owner/year	1,525,000
								Maintenance cost year 3	3,975,000

Appendix S. Acceptability analysis

Table S.1 Justification at the practical level

No	Improvement Plan	Status	Justification
1. Environmental			
1.1.	Optimise the hull maintenance interval	Acceptable	According to the owners, 3 or 4 months is the regular interval for wooden boat maintenance. Occasionally, it can be delayed up to 5 or 6 months due to financial reasons. When this happens, the fishers will do a partial cleaning essentially of the underwater area and emergency repairs if required. Even though the maintenance has been scheduled for the regular period, the owners are not sure if this technique is the most appropriate way to save both fuel and money. Hence, they are interested in identifying if there is an optimal interval for maintenance.
1.2.	Participate in the LPG conversion programme	Implemented	In 2016, the government provided LPG converter kits for small vessels which use engines that are less than 15 HP. This means the programme is only applicable for HL vessels and other typical vessels excluded from this study. The fishers accepted and cooperated with the conversion programme. However, recently, it was confirmed that the continuity of the LPG supply hinders the programme.
1.3.	Manage the speed correctly	Implemented	The skippers understand that managing the vessel's speed could save fuel. However, as the fuel has been allocated for one trip, the skippers usually use it optimally.
1.4.	Participate in the research and development programme	Implemented	The fishers are welcome to be part of the research and development programme as long as they are informed about the project.
1.5.	Participate in the fibreglass conversion programme	Implemented	The fibreglass conversion programme was successfully implemented in 2008, though it is restricted to small vessels less than 3 GT. Consequently, it is only applied to HL vessels and other similar vessels, which are not discussed in this study. The owners and skippers of PD vessels consider that the fibreglass conversion is a good development. They acknowledge that it is applicable for PD operations with some modifications (i.e. using smaller boats). However, they do not want to replace their existing vessels as more investment is required.

No	Improvement Plan	Status	Justification
			Meanwhile, the owners and skippers of TN and LF vessels believe that the fibreglass vessel is impracticable due to safety and durability issues.
1.6.	Break from fishing during the low season	Unacceptable	It is unacceptable for several reasons: 1) Most fishers do not have an additional job, or if they have, the job is typically an occasional odd job which is financially unreliable, and 2) The low season does not necessarily mean no fish. Thus, going fishing might remain profitable yet high risk.
1.7.	Develop awareness of ecosystem quality	Partially implemented	The fishers are aware of protecting the marine ecosystem from destructive fishing gear and exploitation of prohibited species. However, they still catch undersized fish due to financial reasons.
1.8.	Prevent over fishing in the bay	Unacceptable	Local fishers believe that their activities will not cause the fish resources to deplete. Nevertheless, they blame fishing practices that are being conducted outside the bay for preventing the fish from entering the bay.
1.9.	Develop solid and mutual collaboration	Implemented	Proposed for the sellers, fishers and owners. Financial difficulties have forced both fishers and owners to seek help from the sellers. In order to maintain the collaboration, all three groups confirmed that they communicate well with each other. However, it is also undeniable that some problems might appear later on and consequently, cause partnerships to end.
1.10.	Reduce the ice quantity during the low season	Acceptable	According to the fishers, it is possible to reduce the ice provision, especially during the low season. However, similar to fuel, the ice is allocated by the owner before fishing and the fishers use it the most. According to the owner groups, ice is an inexpensive item whose reduction will have an insignificant effect on operational costs. Besides, they claimed it would be better to take a little more.
1.11.	Change the main engine from a two-stroke to a four-stroke engine	Unacceptable	The price of the four-stroke main engine is double its counterpart.
1.12.	Switch from night-time to day-time operations	Unacceptable	Proposed for HL vessels. According to the fishers, most of the hairtail fish in the bay are caught during the night. Furthermore, night time fishing is preferred to day-time fishing.
1.13.	Install additional fenders	Partially implemented	In order to protect the vessels from mechanical damage, some fishing vessels have more fenders than others. It reduces the risk of damage when the vessel is berthing. However, the skippers are

No	Improvement Plan	Status	Justification
			not sure if it also reduces the working load during hull repairs because most of the damage caused by collisions are minor ones.
1.14.	Treat the wood before construction	Acceptable	Prior to construction, no special handling is given for wood. The builder needs to ensure that the wood is dry before assembling. However, if there is a simple and affordable treatment that lengthens wood's durability, the builder is interested in trying.
1.15.	Develop good manoeuvring skills	Implemented	Most skippers have more than ten years' experience and they argued that the vessels had been carefully handled when berthing. However, collisions are sometimes unavoidable and cause major damage. When this occurs, representatives from both vessels will negotiate solutions.
1.16.	Change the EPS box to an HDPE or a fibreglass box	Unacceptable	The fishers prefer to use a polystyrene fish box because it is light, simple and inexpensive. Furthermore, the boxes are sometimes directly sent to the sellers and not necessarily returned to the fishers. In fact, some fishers have an HDPE box onboard their vessels, though it is commonly used to preserve ice or equipment.
1.17.	Use second-hand plastic drums	Implemented	Proposed for the LF platform. According to LF fishers, they prioritise using second-hand drums over the new ones.
1.18.	Optimise the platform size	Acceptable	When building an LF platform, the only constraint is the budget. No calculation is undertaken to evaluate the optimal dimension. However, the LF fishers are interested in knowing the optimal dimension.
			2. Economic
2.1.	Transfer knowledge amongst the fishers	Implemented	It is common for fishers to develop their fishing skills by learning from the experienced ones. Nonetheless, not every newcomer is eager to enhance their knowledge.
2.2.	Amend the sharing system	Unacceptable	For the time being, the owner of PD and TN vessels are reluctant to change the existing share, as they are still responsible for maintenance costs. Conversely, the fishers are content with their portions.
2.3.	Exclude the seller from the value chain	Unacceptable	It is difficult for fishers or owners not to collaborate with the sellers due to the absence of an auction mechanism, financial issues and network limitations.
2.4.	Define the optimum crew number	Partially implemented	Regardless of non-contractual employment, generally, there will be a permanent crew working on the vessel. A temporary substitution is possible on request. However, during the peak season, additional members are allowed to join as long as it does not exceed the maximum capacity.

No	Improvement Plan	Status	Justification
2.5.	The owner is directly involved in the fishing operation	Partially implemented	The percentage of TN and HL vessels directly operated by the owners is 90% and 58% respectively, whilst for PD vessel and LF ferry it is roughly 30% and 13%. Furthermore, no data is recorded regarding ownership of the LF platform. A typical owner who assigns someone else to run the vessel is usually a retired fisher, engaged in another job and a non-resident.
2.6.	Provide the best shuttling service	Implemented	The core business of the LF ferry is an excellent service for the LF platforms.
2.7.	Keep costs at the existing level	Implemented	It is standard that the owner will keep the maintenance costs within the regular budget.
3. Social			
3.1.	Encourage children to complete mandatory education	Partially implemented	By their very nature, fishers do not want their children to give up their education, although the financial situation occasionally forces them to do the opposite. Furthermore, a lack of motivation to study is another major cause of school dropouts, because once the teenagers know how to earn money, they are reluctant to continue their studies. In this case, it is hard to encourage them back to school unless their parents are very strict.
3.2.	Enhance survival skills	Partially implemented	Besides learning fishing skills, some fishers also learn survival skills, especially how to read natural signs of hazards at sea. However, it is also undeniable that not every fisher is aware of the skills that are required.
3.3.	Prepare first aid kits and safety equipment	Acceptable	The fishers are aware of the risks related to fishing. However, the fact that they are accustomed to their working environment has caused them to downgrade preventive and protective measures during fishing trips. Due to unfamiliarity, it is also uncomfortable for them to work using safety equipment, such as safety boot and gloves.
3.4.	Communicate with other vessels or onshore partner to monitor the condition of the sea	Implemented	It is common for fishers within the same fishing gear group to share information about the condition of the sea and fishing ground. Furthermore, the telecommunication network allows fishers to communicate while working at sea.
3.5.	Participate in the insurance programme	Partially implemented	When the FGD was conducted in 2016, the fishers were not aware of the national insurance programme. However, in 2017, they were informed and encouraged to participate in the programme. As a requirement of receiving the free insurance policy, the fishers have to fulfil certain requirements, including holding a fisher’s ID card, bank account and using legal fishing

No	Improvement Plan	Status	Justification
			gear. Data from 2018 illustrates that 1,072 fishers (approximately 34% of the total registered fishers) received the policy with a free premium. It is valid for a one year coverage. For the subsequent years, the fishers have to pay the premium themselves. The premium is inexpensive, roughly Rp75,000 – Rp175,000 per year (~ £4.5 to £10.5). Thus, the fishers should be encouraged to maintain their participation.

Table S.2 Justification at the policy level

No	Improvement Plan	Status	Justification
1. Environmental			
1.1.	Promote the LPG conversion programme	Implemented	As mentioned previously in Table 1, Point 2, the government promoted the LPG conversion in 2016. This is now challenged by the LPG supply mechanism.
1.2.	Support research and development of sustainable fishing vessel design	Acceptable	Generally, the government supports the research and development of the fishing vessel design, even though it is undeniable that more focus is more on the development of fishing gear. Hence, the design of the fishing vessels is rarely improved. Furthermore, a strong belief in the indigenous design hinders the advancement programme. Therefore, a social approach is required when conducting a study targeting technical changes in fishing vessels in order to produce an appropriate solution.
1.3.	Promote the fibreglass conversion programme	Implemented	As mentioned previously in Table 1, Point 5, the government had successfully promoted the fibreglass conversion in Palabuhanratu in 2008. Furthermore, at the national level, during 2010-2014, the government granted fishers hundreds of fibreglass vessels (30GT), in order to encourage them to operate a larger vessel. This programme dealt with incompatibility issues. Hence, since 2016, a further grant was released by providing vessels which meet the fisher's needs. This programme continues to run at present.
1.4.	Implement the seasonal fishing ban	Unacceptable	The seasonal ban is primarily implemented to conserve fish stocks. Thus, it is applied based on the species. In fact, during the low season, bad weather is the major factor restricting the fishers from catching fish. Hence, banning operations during that period will not be in line with the basic purpose of assisting the fish resources to recover. Additionally, this programme requires sufficient and accurate seasonal patterns for each species and therefore, remains a challenging issue in Palabuhanratu.
1.5.	Fish stock assessment of Palabuhanratu Bay	Implemented	Fishery statistics have been used to estimate the maximum sustainable yield (MSY) in Palabuhanratu Bay.
1.6.	Propose management action which considers economic and social impacts	Acceptable	A policy which is designed to preserve fish stock especially should be created by considering the socio-economic aspect of the fisher's life. Nonetheless, prioritising both concerns and satisfying each fishing community member equally is virtually impossible due to conflict of interest.

No	Improvement Plan	Status	Justification
			Therefore, scaling the priority is required. It is also plausible that sometimes the policy has a detrimental effect on a specific group. In this case, the effect should be kept to a minimum.
1.7.	Encourage the seller to be involved in improving fisher's wealth	Unacceptable	The local government acknowledge the seller's role in the fishing business. As part of the value chain, the sellers are asked to collaborate in preserving the marine ecosystem by rejecting banned species from fishers. Nevertheless, asking for further collaboration in improving fisher's wealth is unacceptable, as it indicates the government's failure to answer the fishers' problems.
1.8.	Maintain fish prices	Partially implemented	Fish are considered as a food with a normal supply, with no scarcity problem and an increasing price is still acceptable. Therefore, the government is not involved in price control. However, in 2015, for the first time, the government included mackerel and bullet tuna as basic food whose price is regulated. Furthermore, though the webpage is maintained by MMAF, the fish price in Indonesia is monitored. It can be accessed by the public, although it does not cover every single commodity. It is not online, yet it is up-to-date. Additionally, PPN Palabuhanratu is one of the fishing ports which actively updates its data.
1.9.	Activate a proper auction mechanism	Unacceptable	For the time being, the auction is only conducted for a catch from troll line vessels, with an uncertain schedule depending on the vessel's arrival. Organising a proper auction for all vessels is challenging, due to financial problems, as the organisation which manages the auction should have enough money to anticipate the transaction rate. Furthermore, the fact that most of the vessels have been bonded to sellers, compounds the implementation process.
1.10.	Develop renewable energy for Small Medium Enterprises (SMEs)	Unacceptable	It is not the domain of the MMAF and the local fishery council.
1.11.	Developing greener methods for existing electricity production	Unacceptable	It is not the domain of the MMAF and the local fishery council.
1.12.	Support research and the development of environmentally friendly paint and anti-fouling	Unacceptable	It is not the domain of the MMAF and the local fishery council.

No	Improvement Plan	Status	Justification
2. Economic			
1.1.	Amend the law on the fisheries sharing system	Acceptable	Administratively, it is not the domain of the MMAF. It is the responsibility of the legislative or the local council. However, in this case, the MMAF can propose the amendment as part of the fishers' welfare improvement programme.
1.2.	Maintain the fuel price	Unacceptable	Similarly, this is also not the domain of the MMAF and the local council. It is the authority of the President of the Republic of Indonesia.
3. Social			
1.1.	Monitor the implementation of mandatory education	Unacceptable	It is not the domain of the MMAF and the local fishery council. Nonetheless, they are willing to collaborate if there is a request to report any child labour in the area of their authority.
1.2.	Protect the street children	Unacceptable	It is not the domain of the MMAF or the local fishery council. However, it is mandated by the Indonesian that the state should protect abandoned children including street children.
1.3.	Conduct safety workshops	Acceptable	The fishers' interest in occupational health and safety is minimal. Thus, it is occasionally held by the port authority.
1.4.	Ensure the availability of safety equipment on the fishing vessels	Acceptable	It is required by law that safety equipment in each vessel should be checked as a prerequisite for port clearance, which for small vessels up to 5 GT, is valid for a week. In fact, the implementation is not effective, as most vessels leave the port without a full inspection. The inadequate monitoring system leads to massive infringements in addition to weak law enforcement.
1.5.	Improve accident handling	Acceptable	Officially, accidents at sea are handled by the water police. In this case, the port authority is responsible for helping the search and rescue process besides conducting preventive measures, such as updating the weather conditions, inspecting safety equipment and informing fishers of the accident mitigation system.
1.6.	Disseminate the insurance programme and monitor its implementation	Implemented	Since 2016, it has been gradually implemented as a national programme. As mentioned in Table 5, Point 5, since 2017, the programme has been officially implemented in Palabuhanratu by granting 235 fishers. Subsequently, 837 fishers were awarded the insurance programme in 2018.